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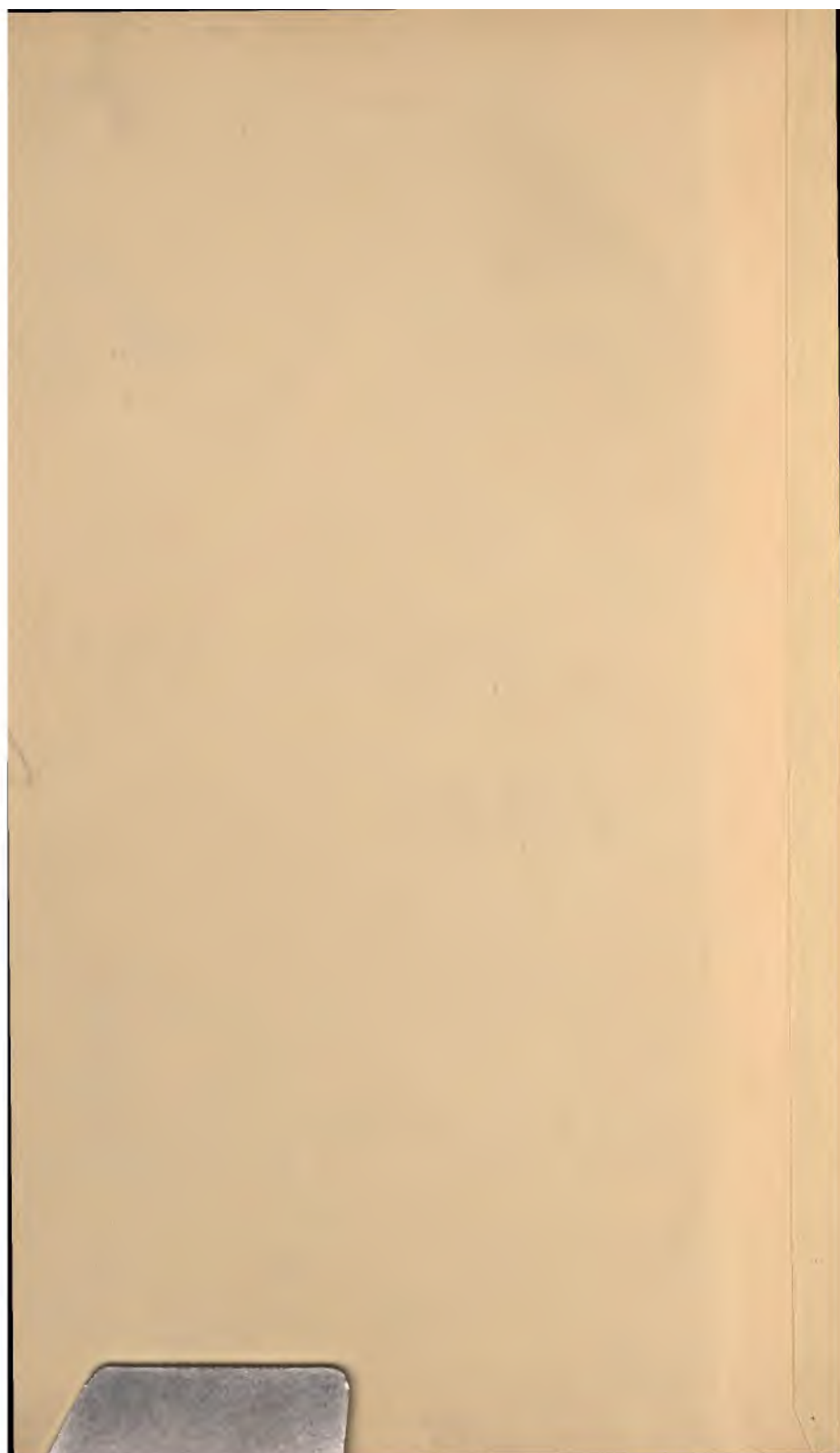
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The Gas Engine in Principle and Practice

Including Comparison of the two-cycle and four-cycle types of Internal Combustion Engines; with Description of Various Designs; together with notes on Suction and Pressure Type Gas Producers, Crude Oil Vaporizers; etc., etc.

Consisting of Articles published in *Gas Power* and other descriptive matter and tables.

Written and Compiled by

A. H. GOLDINGHAM

Mechanical Engineer and Expert. Author of "Oil Engines."

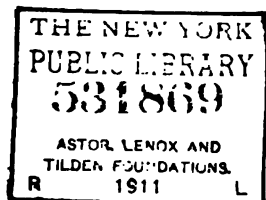
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PREFACE

It has been the desire of the publishers of this book to place before the readers of Gas Power and others, information concerning the internal combustion engine written as plainly and simply as is possible in treating a subject somewhat complex in character. To that end articles published in Gas Power with other matter have been prepared and compiled by the writer. Books of all authorities on the subject have been consulted in preparing this work and it is believed the information contained in the following pages will be found thoroughly reliable and up-to-date. As this work was primarily intended for the non-technical reader endeavor has been made to simplify and explain any necessary calculations, to condense the text as much as possible and throughout to render the work interesting to those desiring information on this subject. The writer wishes to thank those who have given such valuable assistance, especially the manufacturing firms referred to in the text for illustrations, indicator cards, etc., placed at his disposal by them.

A. H. GOLDINGHAM.

New York, June, 1907.

INTRODUCTORY

Historical

Theoretical

Losses

Ratings

It is the desire of the publishers of this book to offer to the readers of Gas Power and others interested in the internal combustion engine information regarding such engines which will enable them to more fully comprehend their operation and understand the advantages obtained by their use. Features of the subject only are discussed which should be useful to those desiring practical knowledge.

In order that readers not familiar with the subject may readily understand, endeavor has been made to render the text as simple as possible and non-mathematical. Slight reference only is made to the theoretical side of the subject while reference to the history of the gas engine and other features not essential to the readers for whom this work is intended is made as brief as possible.

The gas, gasoline and oil engines here discussed may be defined as engines designed to convert heat into work, the heat being supplied by a mixture of gaseous fuel and air and generated by combustion in the engine cylinder, a movable piston in the cylinder being arranged against which the energy evolved by the expansion of such heated gases acts. These engines derive their power from the combustion of illuminating gas, natural gas, producer gas, blast furnace gas, oil gas, etc. They are made in various designs as shown in Chapter II, the details of construction, the igniting and speed governing devices being described in Chapters following. Instructions for installation and operation and the

INTRODUCTORY

cost of working and constituents of the gases referred to are also discussed.

Nearly everyone is familiar with the steam engine, in which the working fluid or heat conveyor is steam generated in the boiler and allowed to expand, converting heat into work in the steam engine cylinder. The gas engine operates similarly, gas being used instead of steam. In some ways the steam engine is a simpler apparatus than the gas engine, as in the steam engine cylinder a physical process only is performed while in the gas engine a chemical process is gone through.

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CHAPTER I.

HISTORICAL.

Brief reference to the gas engine historically shows that the first engine to obtain its power by explosion was made at Orleans, France, in the seventeenth century, the fuel used being explosive powder, the power being obtained by a partial vacuum following the exploding of the powder.

The first engines to derive their motive power from inflammable gases from coal were patented and made by Englishmen named Barber and Street in the end of the eighteenth century while about 1800 a French engineer patented a gas engine of the double-acting type with separate air and gas pumps but this ingenious inventor did not perfect all of his ideas.

The commercial possibilities of the gas engine were not recognized until about 1860 when Lenoir took out his first patent. The engine by this inventor was of the non-compression type, that is, there was no compression of the gases in the cylinder before explosion. This, with various engines of the same type, that is, non-compression, were built when in 1862 M. Beau de Rochas invented the cycle of operations known by his name, now frequently referred to as the four-cycle engine, the Otto-cycle. In this engine the compression of the explosive mixture in the cylinder was performed before ignition took place.

The most important laws of this cycle he laid down then, namely:

GAS ENGINE PRINCIPLE AND PRACTICE.

1. The greatest volume of cylinder with least exposure of surface.
2. Highest possible piston speed.
3. Greatest range of expansion of gases.
4. Greatest possible pressure in the cylinder before ignition.

These points all still hold good and it is interesting to note how in the various types of engines, they have been carried out. In examining the different engines on the market, especially of the single cylinder type, one is impressed with certain important differences—due chiefly to the two different cycles of operation.

While by far the greater number of engines operate on the four-cycle (the same as Beau de Rochas or Otto cycle), still a large number of engines operate on the two-cycle plan.

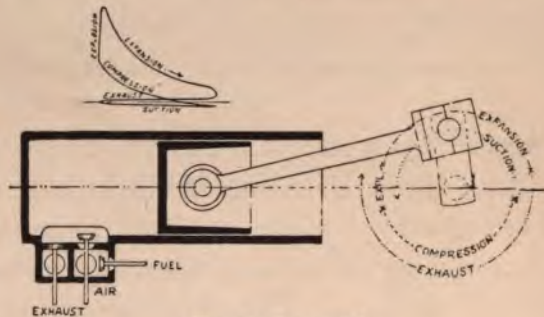


Fig. 1—Four-cycle.

The two-cycle is sometimes known as the "Clerk" cycle, it having been developed by the well-known authority, Dugald Clerk. Two accompanying diagrams show the method of operation of these cycles. From them it will be seen that the "Otto" or four-cycle requires four strokes:

1. Suction;
2. Compression and ignition;

HISTORICAL.

3. Expansion or working stroke;
4. Exhaust.

That is, this cycle requires four motions of the piston or two revolutions of the crank to complete it.

The different strokes of the four-cycle are indicated on the path of the crank pin. And, also, against each corresponding period the pressures per square inch of the piston are shown by the indicator diagram at the side.

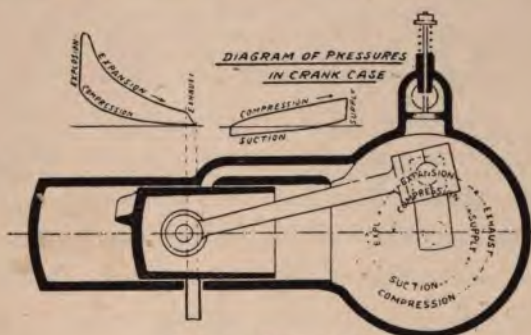


Fig. 2—Two cycle.

In the two-cycle type it will be noted the compression is effected in the crank chamber which is suitable for the smaller size engines only. Engines of over 35 horse power and of single cylinder have the compression effected in separate compressing cylinders as explained in Chapter II.

In Fig. 2 the indicator diagrams taken from both the cylinder and crank chamber are shown. It should be remembered, however, that the pressures indicated in the crank case diagrams are exaggerated—that is, they are not on the same scale as the working cylinder diagram since they represent pressure shown by the movement of a weaker spring in the indicator.

In actual operation the pressure obtained in the crank chamber is at its maximum, only three or four pounds per

GAS ENGINE PRINCIPLE AND PRACTICE.

square inch, whereas the maximum pressures on the working end reach 200 pounds per square inch and more.

In 1878 was shown at Paris the "Otto Silent Engine," patented in 1876 by Dr. Otto, the famous German engineer. This engine worked on the Beau de Rochas cycle as already outlined, the chief claim for the Otto engine being the stratification in the cylinder of the mixture of gas and air with also a portion of the products of previous combustion left in the cylinder adjacent to the piston to act as a cushion, thus deadening the shock of the explosion, pure air being drawn into the cylinder during the early part of the stroke followed by mixture of air and gas. In practice stratification was only partly effected but the slow combustion of the charge (which was ignited by flame) was a distinct improvement over previous engines and its smooth and even running claimed for it the title of the "Otto Silent Engine." This was undoubtedly the forerunner of thousands of successful gas engines manufactured on similar lines but with improvements in details as described in the following chapters.

TWO-CYCLE ENGINES.

The disadvantage of the Otto engine with its impulse every other revolution prompted several inventors to bring out engines working on the two-cycle plan, that is, to obtain an explosion at each revolution of the crank pin. In 1881 James Atkinson patented his remarkable differential gas engine designed to reduce the loss of heat to the water jacket and exhaust by obtaining an explosion each revolution of the crank. The motor cylinder was fitted with two pistons operating in opposite directions and acting through levers on a common crank pin. In this engine rapid expansion of the gases beyond their original volume took place, the burnt

HISTORICAL.

products being fully expelled from the cylinder. The water jacket only covered a small part of the cylinder.

In 1886 the Cycle gas engine was patented by this inventor. As the manufacture of these engines has been discontinued in this limited description no further reference will be made to them.

CLERK ENGINE.

Of the many gas engines then made of the two-cycle type, where the compression was performed in an auxiliary or separate cylinder, the Clerk engine was the most prominent originally; shown in section at Fig. 3. Recently this engine has again had considerable attention and therefore it will not be out of place to refer to it somewhat in detail here.

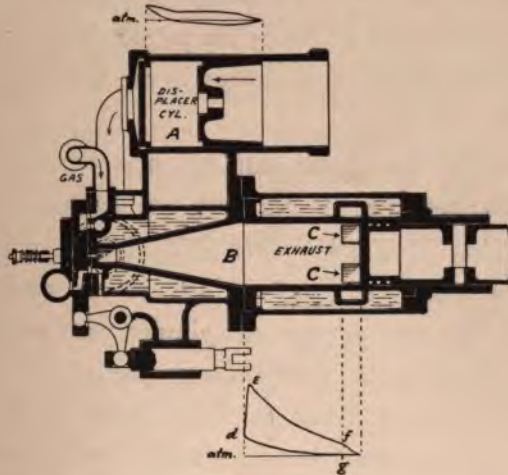


Fig. 3.

The figure shows a sectional view through the pump and the working cylinders. The Clerk engine was amongst the first motors of this type, being put upon the market nearly thirty years ago. In this engine the mixture of gas and air

GAS ENGINE PRINCIPLE AND PRACTICE.

is first compressed in the pump "*A*" where it reaches a pressure of approximately six pounds and then is delivered to the motor cylinder, "*B*," where ignition takes place, with compression of 40 pounds and initial pressure of about 180 pounds at full load, an impulse being had each revolution. The mean effective pressure at full load was 60 pounds.

The disadvantage of the Otto cycle type engine of having its impulses at every other revolution is here obviated, and an impulse each revolution secured. The number of impulses being doubled, a greater power was obtained from the same sized motor cylinder without necessitating increasing the strength of the reciprocating parts.

The indicator diagrams in the figure show the different processes performed in the cylinders and the periods during which they take place. In the pump, or displacing cylinder, *A*, during the forward stroke of the piston, a mixture of gas and air required for the next charge in the working cylinder, is drawn in.

At the end of the stroke only air, however, is taken in, which is arranged not to mix with the explosive mixture. Experiment has long since furnished the proof that two different gases, such as gas and air, or air and mixture, cannot be drawn into a working cylinder without becoming intimately mixed in the very shortest period of time.

During the return stroke of this piston the scavenging charge of air is emitted into the motor cylinder followed by the charge of explosive mixture. The operation in the motor cylinder allowed explosion of the mixture at constant volume or nearly so during the period marked in the diagram, *d, e*, which was followed by expansion of the burning gases during the period shown at *e, f*. The exhaust ports are

HISTORICAL.

shown at *CC* in the sectional view and accordingly as soon as the piston uncovers these ports the period of exhaust begins. This is shown on the diagram between *f* and *g*. During this period the exhaust is completed and the charge of air and then the mixture from the displacing cylinder enters the motor cylinder, thus allowing the products of combustion to be completely discharged. The period of compression of the mixture being performed during the period marked *g d*.

In the majority of engines running at speeds at which they are designed to run the mixture enters at a rate that is as great as 5,000 to 6,000 feet a minute; so that with a stroke of one foot and a speed of the engine of 300 turns a minute and an assumed speed of entry of only 3,000 feet a minute, they have time to travel ten times the length of a cylinder during a stroke. And further than that, practically all the chemical tests of the exhaust from engines of the Clerk and the Day (closed crank case engines) and similar two-cycle engines in which the incoming charge forces out the remains of the exhaust, this exhaust is found heavily charged with unburnt fuel.

On the first uncovering of the exhaust port by the piston on such engines, about two-thirds of the exhaust (which is at about 30 pounds pressure) escapes. This portion is fully burnt. The other part, however, which is forced out after the opening of the inlet port, is composed of nearly 40% mixture and 60% burnt gas, showing that almost instantaneous mixing of the old and the new charges takes place. This accounts for the extremely pungent odor always noticeable when the exhaust from a two-cycle engine is allowed to escape into a poorly ventilated room.

The amount of fuel wasted with the exhaust computed from these figures, is one-third of 40%—or, in round numbers,

GAS ENGINE PRINCIPLE AND PRACTICE.

13 per cent.; a figure that is not far out in giving the lowest relative difference in economy in fuel between similar sized two-cycle and four-cycle engines. That is, for the same power a two-cycle engine burns at least 13 per cent. more fuel than a four-cycle engine, when engines of about the same power are compared.

Variation in design and arrangement of engines based on the theory and method of operation of the engines already referred to are shown in Chapter II.

MEASUREMENTS.

It has been stated that in the gas engine heat is converted into work. This work is measured in English speaking countries by the term "foot pound," and the term "horse power," that is, the rate of doing work is spoken of as 1 H. P., which is the equivalent to 33,000 ft. lbs. of work per minute; that is, the raising of 33,000 lbs. one foot high or one lb. 33,000 feet in one minute.

Heat is measured by the "British Thermal Unit" (B. T. U.), that is, the amount of heat energy necessary to raise the temperature of one pound of water one degree Fahrenheit at 60° F. is known as 1 B. T. U.

The mechanical equivalent of heat known as "Jule's equivalent" is 778 ft. lbs. of work = 1 B. T. U.

$$\text{Thus } \frac{33000}{778} = 42.42 \text{ B. T. U. per minute, or } 2,545$$

B. T. U. per hour is equivalent to 1 H. P.

RATINGS.

The steam engine is usually rated on the Indicated Horse Power, while the gas engine is generally rated on the

HISTORICAL.

actual or brake horse power, that is, each actual or brake horse power must be equivalent to the raising of 33000 lbs. one foot high per minute, the indicated horse power being measured by an instrument known as an indicator. See Chapter V where the methods of measuring the power of the engine and the necessary formulae for ascertaining results obtained are described.

In the action of the gas engine, part of the heat generated by combustion is spent in performing mechanical work the remainder being rejected by the engine still in the form of heat. The water jacket around the cylinder and combustion chamber (in larger engines in the piston also) required to preserve proper lubrication is necessarily a great source of loss of heat while the exhaust taking place at considerably above atmospheric pressure forms another source of loss.

All heat engines take in heat at a comparatively high temperature rejecting heat at a comparatively low temperature the difference between the two being converted into work, thus,

Heat evolved=work+heat losses.

The greater the range of temperature between the initial and final temperature the greater amount of work will be performed.

The ideal engine would convert into work the fraction
of heat $\frac{T_1 - T_2}{T_1}$ of the total heat supplied.

T_1 =absolute initial temperature or receptive temperature.

T_2 =absolute final temperature or rejective temperature.

To obtain the greatest economy therefore the engine must

GAS ENGINE PRINCIPLE AND PRACTICE.

work with the highest initial temperature and with the greatest range of expansion. The decrease in consumption of fuel in the later gas engines is almost if not entirely due to the increased pressure of compression of the gases before ignition. By increased compression or decreased clearance in the cylinder the following advantages have been gained:

(a) Minimum cooling surface of cylinder walls in contact with gases at explosion period.

(b) Rapidity of combustion and quick conversion of heat into work.

(c) Greater range of expansion, the maximum pressure and temperature being reached immediately on explosion.

(d) Consequent increased thermal efficiency.

The very low economy of the first gas engines (the Lenoir or non-compression type) required at least 95 cu. ft. of gas to develop one B. H. P. has been increased by the increase of pressure of compression before ignition in the cylinder, that is, the initial temperature has been increased while the final temperature remains the same so that in present gas engines a B. H. P. has been developed by consuming 16 feet of illuminating gas or about 9,000 B. T. U.'s per hour.

THERMAL EFFICIENCY.

The thermal efficiency of an engine is the ratio of heat utilized by the engine as compared with the total heat contained in the fuel absorbed by the engine and can be arrived at by the following formula:

$$\frac{2545 \text{ B. T. U.}}{\text{B. T. U. consumed per B. H. P. hour.}}$$

B. T. U. consumed per B. H. P. hour.

HISTORICAL.

As an illustration, if the work performed by an engine while consuming one pound of fuel, equivalent to 22,000 B. T. U. were shown to be 2. B. H. P. for one hour, the thermal efficiency of this engine would be represented by

$$\frac{2545 \times 2}{22,000} \text{ being } 23.3\%.$$

HEAT LOSSES.

As the thermal efficiency of the average internal combustion engine is approximately 25%, being about 30% in the maximum* and as low as 12 to 15%, the question may naturally be asked, what causes this great loss of efficiency? These have been classified as follows:

- a. Friction in the engine itself.
- b. Loss of heat to the water jacket surrounding the cylinder.
- c. Loss of heat through the exhaust.
- d. Leakage and other losses.

The following table shows the average percentage of these losses.

Heat converted into work 25%.

Heat ejected in the water jackets 35%.

Heat ejected in the exhaust 35%.

Other losses 5%.

While the thermal efficiency of the internal combustion engine has exceeded 35%, the thermal efficiency of the best steam engine is only approximately 12%. The thermal efficiency of the steam turbine is 12-15% taking into consideration all the losses due to the auxiliaries. The thermal efficiency of the average oil engine is from 15 to 19%. Tests

*Taking the brake H. P.

GAS ENGINE PRINCIPLE AND PRACTICE.

on the Diesel engine in Europe have shown an efficiency as high as 41%*.

EFFICIENCY OF GAS PRODUCER AND ENGINE.

The former remarks have reference to the efficiency of gas engine only and have not taken into consideration the loss in the gas producer.

Prof. Robinson refers to the combined efficiency of the gas producer and gas engine.* He states the thermal efficiency of the gas producer to be 70 to 80% and taking the mechanical efficiency of the gas engine at 80 to 90%, the total efficiency of the whole plant, gas producer and engine at full load is $80\% \times 35\% \times 90\% = 25\%$, the average performance being somewhat lower, probably about 15%.

INCREASED EFFICIENCY.

The increased efficiency due to increased compression has been referred to. In practice the pressure of compression in the gas engine of thirty years ago of 35 lbs. with illuminating gas with mean effective pressure of 60 pounds has been increased in present practice to 90 pounds and more with engines using producer and blast furnace gas. The mean effective pressure in the cylinder while depending primarily on the pressure of compression is dependent also upon the efficient design and other conditions. It is the purpose of the engine builder to carry the pressure of compression to the highest limit without causing pre-ignition.**

The formula proposed by Prof. Grover

$$\text{Mean Effective Pressure} = 2C - 0.01C^2.$$

*Taking the indicated H. P.

*Gas and Petroleum Engines, page 10, Chapter I.

**Modern Gas and Oil Engines, Prof. Glover.

HISTORICAL.

Where c =compression pressure in pounds per square inch above atmosphere may be taken as the most representative formula yet suggested but it would require variation to fit all conditions.

PRESSURES OF COMPRESSION.

The following may be taken as representative compression pressures and corresponding M. E. P.'s. But as such a variety of conditions in various gas, gasoline and oil engines obtains at present they can only be taken as fairly representative.

	Compression above Atmosphere	M.E.P.
Blast furnace gas	150	60-70
Producer gas	90-140	65-75
Natural gas	120	75-85
Illuminating gas	85	80
Gasoline	85	75
Fuel, crude oil, kerosene	50-75	38-75

CHAPTER II.

VARIOUS TYPES OF ENGINES.

Comparison of the Two and Four-Cycle Types.

It is intended in this discussion to compare the types of engines only; space does not allow of reference to all detail parts of different engines.

Practically all internal combustion engines are now made to operate on the two or four-cycle plan and accordingly these two types will be those only discussed here. The principle of the cycles has already been explained in Chapter I. In recent years so many variations in the arrangement and design of the cylinders has been made that it is necessary to record the exact relation of the frequency of impulses obtained with each type. On the accompanying diagrams (Fig. 4) the frequency of impulses is shown as they occur with the various engines. Each space marked 1, 2, 3, etc., represents a stroke of the piston; thus eight strokes or four revolutions are shown. In the indicator diagram (see Fig. 4) the pressure obtaining is represented by the height of the line above the atmospheric line and so here the period when an impulse at the piston takes place is denoted by the vertical rise of the line in somewhat similar form to that of the indicator diagram. As these diagrams are intended only to show the frequency of impulse, no record is shown of the slight back pressure which might exist during the exhaust stroke; the suction period is also represented at atmospheric pressure. Diagrammatic illustrations accompanying shown the arrangement of cylinders

VARIOUS TYPES OF ENGINES.

FREQUENCY OF IMPULSES WITH DIFFERENT TYPES.

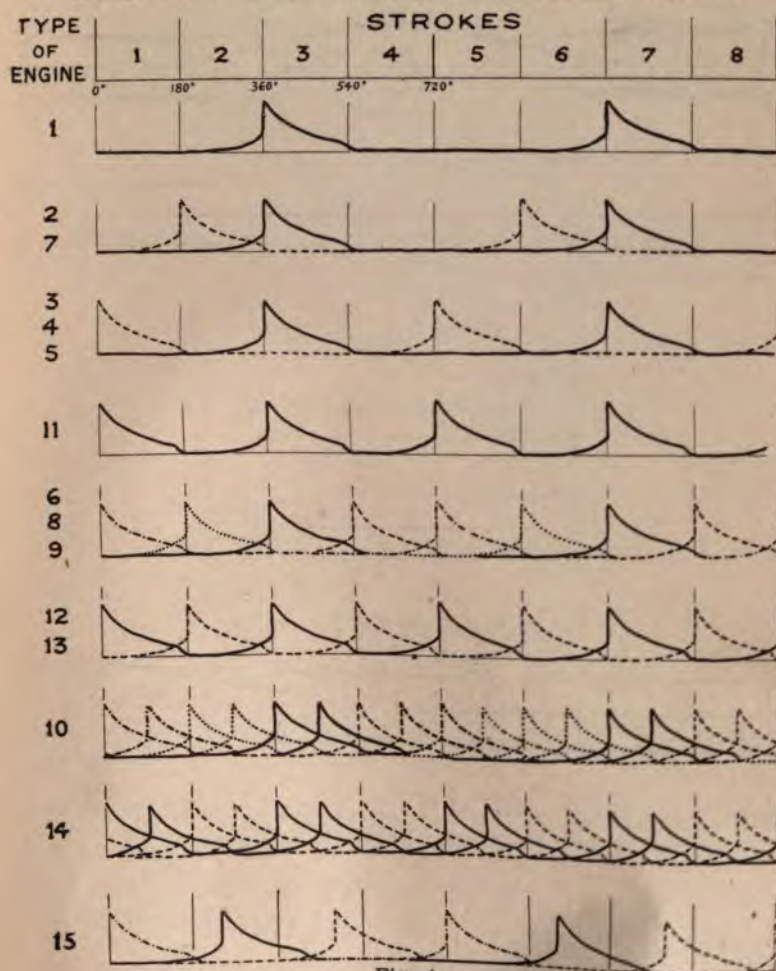
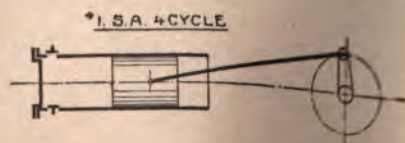
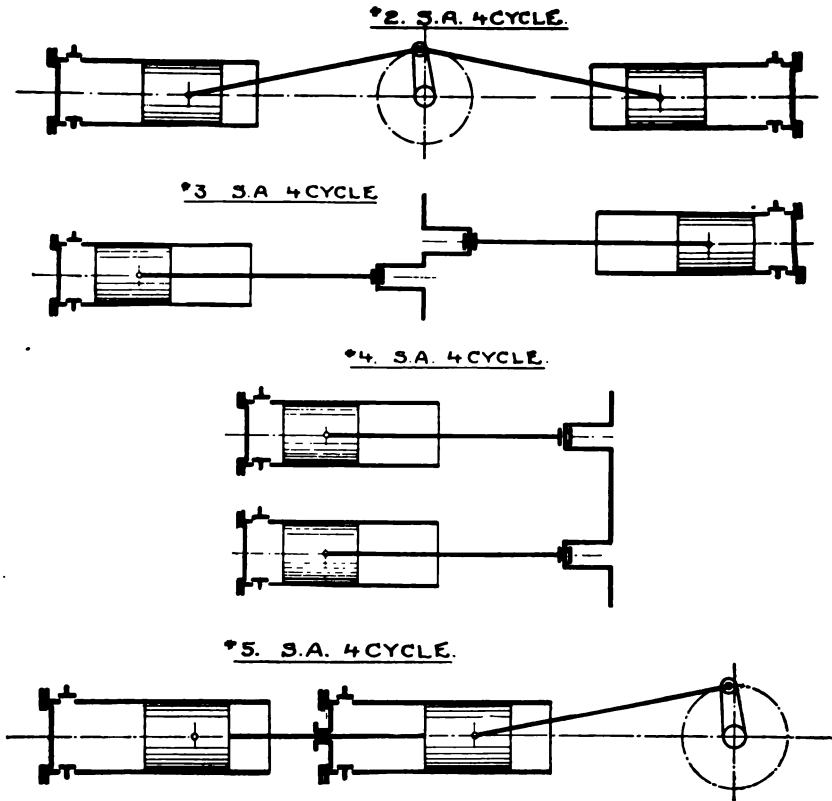


Fig. 4.

in each type. Table I gives the description of each type, being numbered correspondingly. Where more than one cylinder



GAS ENGINE PRINCIPLE AND PRACTICE.



is used the result obtained in the first cylinder is shown in a full line, the result in the next cylinder is shown by a dash and dot line while a dotted line shows the result of the following cylinder in Nos. 6, 8, 9, 10 and 14. This illustration takes no account of the action of the governor and assumes each type to be working at full load with a full impulse continually.

TABLE I. VARIOUS TYPES OF ENGINES.

- | | | |
|------|----|---|
| Type | 1. | 4-cycle, single acting, single cylinder. |
| Type | 2. | 4-cycle, single acting, 2 cylinders opposed. One crank. |

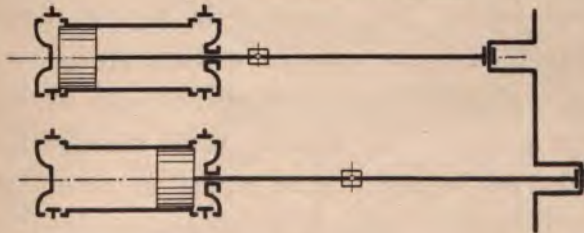
VARIOUS TYPES OF ENGINES.

- Type 3. 4-cycle, single acting, 2 cylinders opposed, cranks 180° apart.
- Type 4. 4-cycle, single acting, twin cranks 360° apart.
- Type 5. 4-cycle, single acting, tandem.
- Type 6. 4-cycle, single acting, 2 twins opposed, 2 cranks 180° apart.
- Type 7. 4-cycle, double acting, single cylinder.
- Type 8. 4-cycle, single acting twin, cranks 180° or 360° .
- Type 9. 4-cycle, double acting, tandem.
- Type 10. 4-cycle, double acting, twin tandem, 2 cranks 90° apart.
- Type 11-11a. 2-cycle, single acting single cylinder.
- Type 12-12a. 2-cycle, single acting, twin, cranks 180° .
- Type 13. 2-cycle, double acting, single cylinder.
- Type 14. 2-cycle, double acting, twin, cranks 90° .
- Type 15. 4-cycle, single acting 3 cylinder, cranks 120° .

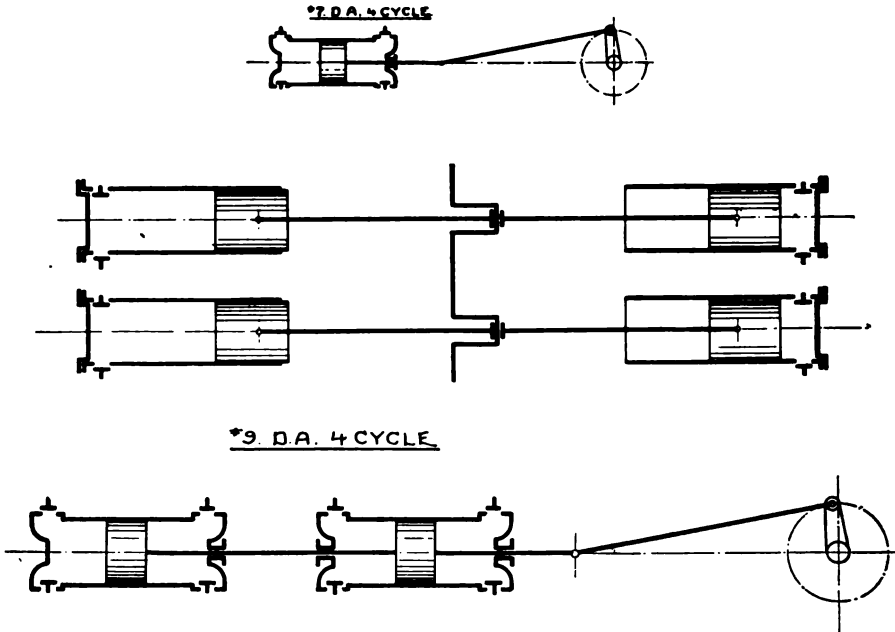
COMPARING THE TWO AND FOUR-CYCLE TYPES.

Large gas engines require the taking into consideration of a great many features not within the scope of this work. The end to be attained in the design and arrangement of the engine being to obtain highest thermal efficiency, greatest mechanical efficiency, to occupy least floor space while reducing the weight of the engine consistent with reliable and uninterrupted continued operation.

*6. D.A. 4CYCLE.



GAS ENGINE PRINCIPLE AND PRACTICE.

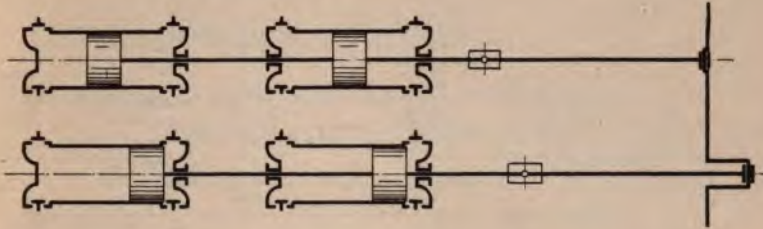


With the four-cycle single acting type necessitating cylinders of large dimensions difficulty is often experienced in obtaining sound castings besides necessitating very large tools for machining enormous masses of metal. Then in operation the cooling surface to which the gases in the combustion space are exposed being decreased (the volume increases as the cube of the diameter, whereas the surface increases as the square of the diameter) the gases in the larger cylinders do not admit of cooling so readily and consequently higher compression before explosion is not possible without pre-ignition. As large gas engines are required to operate with the producer and other gases of low calorific value necessitating high compression this feature must be important. Then again the heavy reciprocating parts of the larger engines and the

VARIOUS TYPES OF ENGINES.

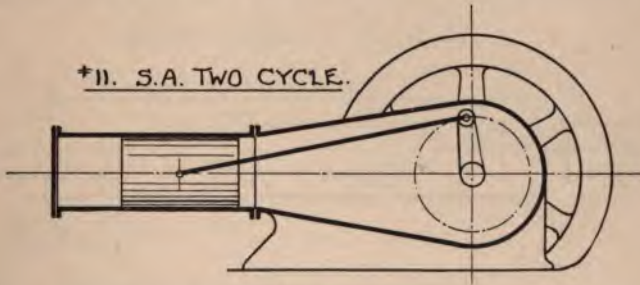
heavy flywheels necessary to maintain even rotative speed tend to reduce the mechanical efficiency of the engine.*

*10 D A 4 CYCLE.



The space occupied must also be considered which with the single acting four-cycle engine is very much greater than is required for the two-cycle engine or the tandem four cycle. While taking into consideration the increased weight the increased first cost must also be greater. Examination of the

*11. S.A. TWO CYCLE.



different makes of American and European large gas engines which are nearly all of the horizontal type shows the tendency of design in the four-cycle type is toward tandem cylinders (see No. 10 in Fig. 4 and table I) and of the double acting type.

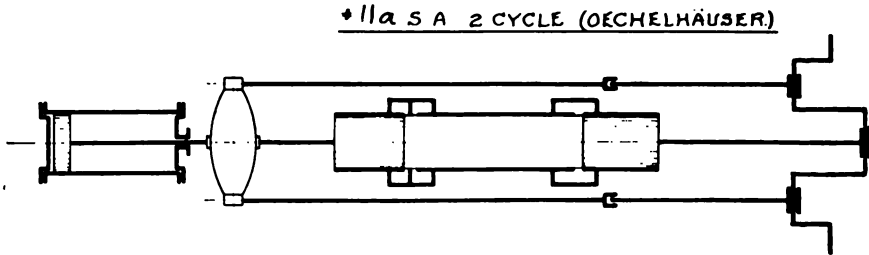
FOUR-CYCLE TYPE.

The main advantages claimed for the four cycle are:

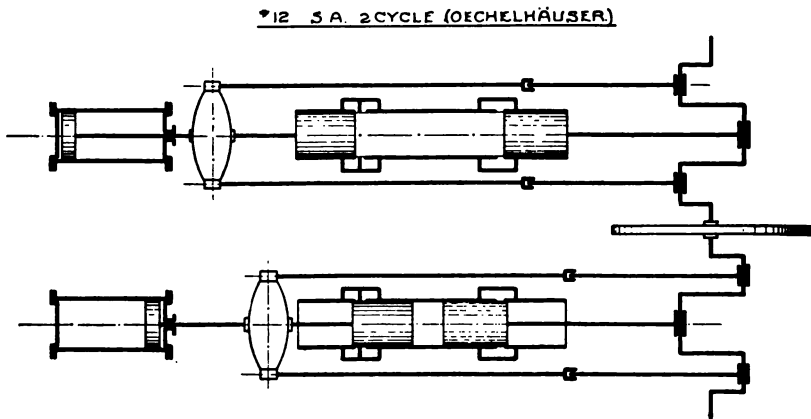
*As an instance the weight of a 500 H. P. four-cycle single cylinder engine has been designed requiring a flywheel of 60,000 lbs.

GAS ENGINE PRINCIPLE AND PRACTICE.

a. More complete combustion of the gases, due to partial scavenging or cleaning out of the burnt charge with fresh air (in some makes of engines) but chiefly to the more complete



filling of the cylinder with the new charge and to the more complete expulsion of the products after combustion which results in the more complete utilization of the fuel introduced into the cylinder.



b. Lower temperature prevailing in the cylinder and inlet passages (by reason of the fewer explosions and the more complete expulsion of the burnt products) thus allowing a greater weight of charge (by reason of its lower temperature) to enter the cylinder.

VARIOUS TYPES OF ENGINES.

c. In the larger sizes greater rotative speed than is possible with the two-cycle type.

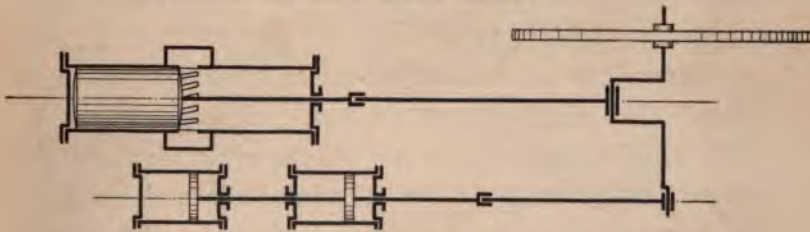
The corresponding disadvantages of the four-cycle are:

*12a. S. A. 2 CYCLE.



a. The fewer impulses; necessitating three (instead of one) idle strokes of the piston and consequently greater cyclic variation requiring very heavy flywheels with the single acting type.

*13. D.A. 2 CYCLE (KOERT'G.)



b. Large piston area per horse power and therefore, with some engines increased weight of engine as compared with the two-cycle type.

There should perhaps be excluded from this the ordinary small sized two-cycle engine, which is the type generally used on launches, etc.

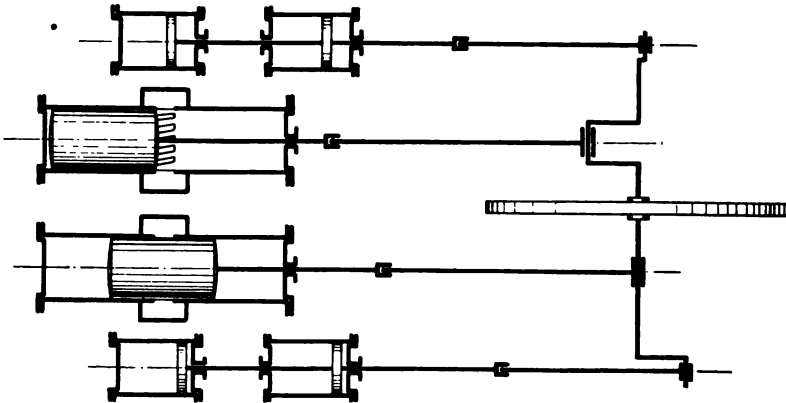
TWO-CYCLE TYPE.

The advantages of the two-cycle type may be thus stated:

GAS ENGINE PRINCIPLE AND PRACTICE.

a. Greater frequency of impulse, consequently decreased weight of flywheel, especially so where variation in angular velocity of the crank pin is important.

* 14. D.A. 2 CYCLE. (KOERTING)



b. Decreased piston area per horse power as compared with the four-cycle and in some cases decreased total weight of engines per horse power.

c. Elimination of exhaust valves and the mechanism to operate valves necessary with the four-cycle engine.

The chief disadvantages of the two-cycle type are the increased temperature of the cylinder walls and passages. The decreased economy, and (with some fuels) the inferior combustion in engines of the smaller sizes where compression is effected in the crank case.

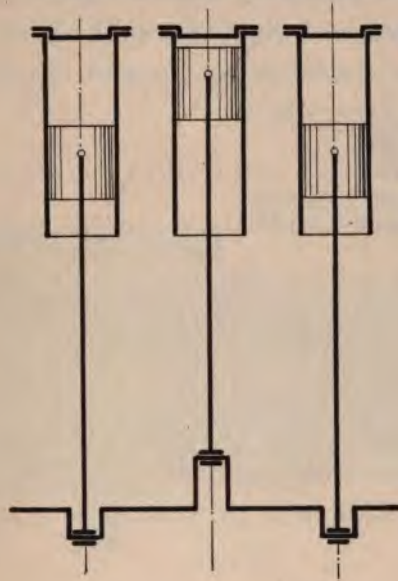
GENERAL REMARKS.

The disadvantages of infrequency of impulse in the four-cycle engine is overcome by increasing the number of cylinders, or by the use of double acting cylinders. This is generally done where steady running is required, such as the

VARIOUS TYPES OF ENGINES.

operating of generators for electric lighting and similar purposes. The multiplicity of cylinders and impulses being essential in cases where the engines are to operate alternating current generators in parallel.

*15. S.A. 4 CYCLE (3 CYL.)



The disadvantage of the two-cycle engine above referred to is due mainly to the improper expulsion of the exhaust gases. This is overcome by using a separate air pump to scavenge or clean out the burnt charge in the explosion cylinder by means of a volume of air passed through it (and out of the exhaust) as the fresh charge enters.

The higher temperatures of the cylinder walls referred to may possibly be decreased by a more plentiful supply of cooling water, and in some cases by increased cooling surface.

In the small two-cycle engines it is usual to perform the process of compression in the crank chamber: as this elimi-

GAS ENGINE PRINCIPLE AND PRACTICE.

nates practically all valves, valve motion and auxiliary cylinders and the friction resulting from the operation of such apparatus, but it is frequently found objectionable when it is required to take the engine apart as the crank chamber, being air tight, the piston, crank bearings, and other moving parts cannot be made so accessible as in the four-cycle engine.

The disadvantage of the inaccessibility is obviated in the two-cycle engine where the compression is performed in a separate or auxiliary cylinder.

COMPARISON OF MECHANICAL EFFICIENCY.

Dr. Lucke compares the mechanical efficiency of the two and four-cycle engines of various sizes stating that in fair average cases* the mechanical efficiency of the smaller size two-cycle engine varies from 63 per cent. to 70 per cent.: with similar four-cycle engines 74 per cent. to 80 per cent.: medium size, two-cycle, 64 per cent. to 66 per cent.: four-cycle, 79 per cent. to 81 per cent., and with 500 I. H. P. and over, two-cycle 63 per cent. to 70 per cent., four cycle, 81 per cent. to 86 per cent.

VARIOUS ENGINES DESCRIBED.

As it is impossible within the limits allowed for this work to refer to the very large number of excellent gas engines now being made both of large and small sizes, only what may be considered as representative gas engines of each type, namely, four-cycle single acting, four-cycle double acting, and two-cycle single acting and double acting are described to give a better understanding to the foregoing remarks.

The Koerting gas engine shown in section at Figs. 5, 6, operates on somewhat similar lines to the Clerk engine, re-

*Gas Engine Design, by C. E. Lucke, Ph. D., page 5.

VARIOUS TYPES OF ENGINES.

ferred to in Chapter I. It will be seen from the illustration that an explosion occurs at each end of the motor cylinder, the exhaust being emitted through the ports placed in the center of the cylinder while the charge of air and gas is compressed in auxiliary cylinders placed parallel with the motor cylinder.

The engine proper consists of cylinder G, Fig 5, having a large inlet valve at either end and a number of diagonal exhaust ports in the center and a water cooled piston K,

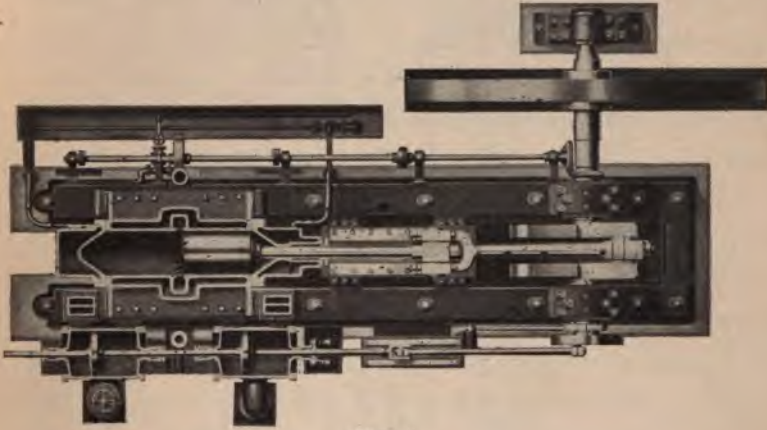


Fig. 6.

which occupies nearly half the cylinder volume. At the side of the main cylinder are two smaller ones, one for handling

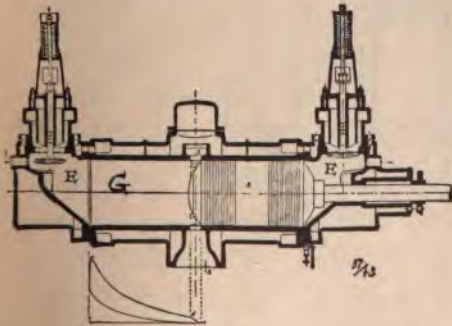


Fig. 7.

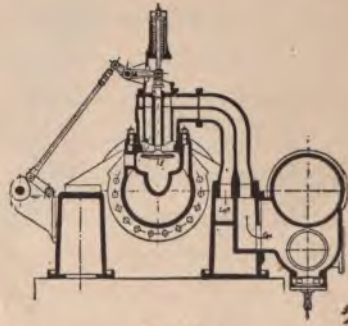


Fig. 8.

GAS ENGINE PRINCIPLE AND PRACTICE.

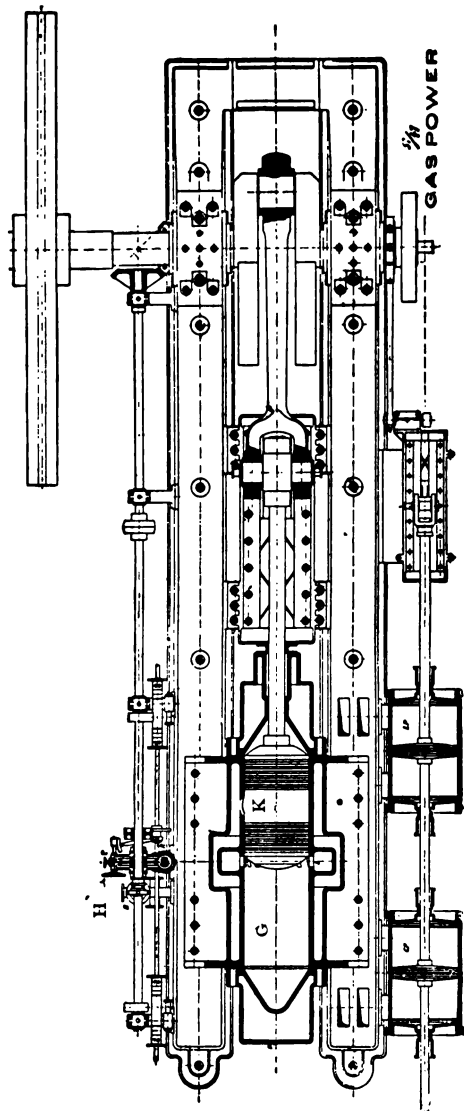


Fig. 5.

VARIOUS TYPES OF ENGINES.

the scavenging or cleaning charge of air, the other the gas. These smaller cylinders are double acting and are operated from a crank disc at the side of the engine.

The action is as follows: Beginning with the explosion stroke at the rear end of the main cylinder, the piston is driven forward until the end of the piston uncovers the exhaust port in the center of the cylinder. This permits the exhaust, which is under some 30 or 35 pounds pressure, to escape. In the meantime the air and gas cylinders have traveled part of the way back, compressing their charges before them. During the time the exhaust port is uncovered by the piston the pistons of the smaller cylinders complete their stroke, the compressed charges through separate concentric ports reach the main inlet poppet valve. Interposed between the small cylinders and the large are two separately timed piston valves. These piston valves are so arranged that on the instant of the main working piston beginning its return stroke the compressed air is allowed to blow through the main inlet valve E, Fig. 7, into the main cylinder, where it carries out the balance of the burned products. A trifle later, and before the air chamber is quite stopped, the piston valve of the gas cylinder opens and the gas is allowed to flow in with the air.

The timing of the various operations taking place in the cylinders is such that the exhaust ports are opened by the movement of the piston about 40° before the crank reaches the outer dead centre and the exhaust is closed again when the crank pin has passed the outer dead centre by the same number of degrees. The air inlet valve is opened to allow air at eight or nine pounds pressure previously compressed by the air pump at 20° from the outer dead centre. The air inlet valve closes again when the crank pin has traveled about

GAS ENGINE PRINCIPLE AND PRACTICE.

75°. The explosive mixture enters shortly after the air inlet is opened. The interval between the opening of the air inlet and the admission of the explosive mixture allows the partial expulsion of burnt gases through the exhaust.

The piston in the working cylinder on its return stroke compresses the charge to about 128 pounds to the square inch, which on being exploded by the electric spark, completes the cycle.

In the front end of the cylinder exactly the same process is repeated at each revolution. The engine inlet valves being opened with, rather than against, the pressure require but comparatively small power to operate them, and as a consequence quite a small sized cam shaft is sufficient, since it has no exhaust valves to lift.

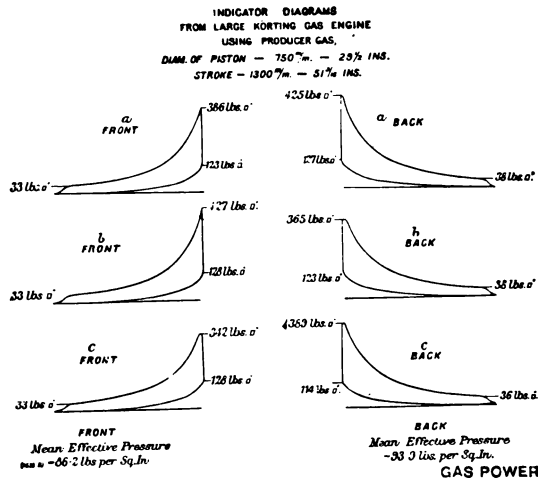


Fig. 9.

Running parallel with, and driven by, the cam shaft is a smaller shaft from which the igniters are operated. The smaller shaft has a sliding gear fitted to a spiral key-way longitudinally, so that shifting the gear longitudinally alters the

VARIOUS TYPES OF ENGINES.

time of making the spark. This is done by means of the hand wheel H, Fig. 5. The main piston is hollow and water cooled and is shown in section at Fig. 10, the circulation being forced through the hollow piston rod by means of a set of hollow links resembling, in some respects, a jointed gas burner bracket. Fig. 11 shows the cylinder in section in which the inner liner is made separately from the outer casing to allow for expansion. Fig. 12 shows the cylinder in section with stuffing box at each end while the motor cylinder head and stuffing box is shown at Fig. 13. By reference to Fig.

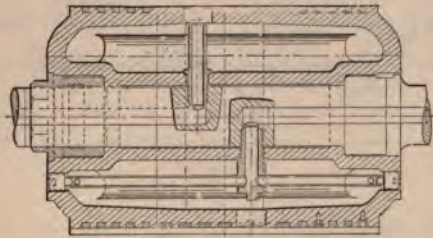


Fig. 10.

5, and the diagram, Fig. 9, the principles of operation will be easily followed. Fig. 9 reproduces some diagrams from large gas engines of this type.

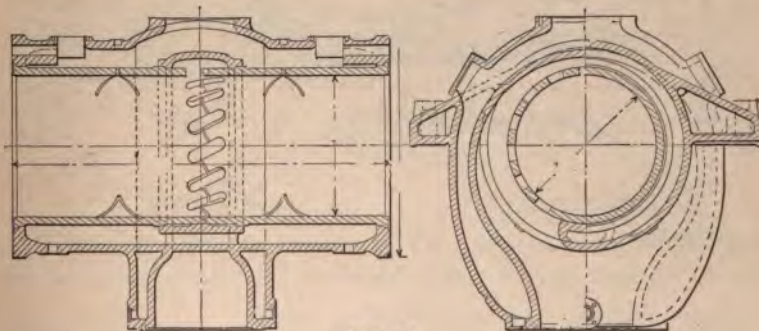


Fig. 11.

As two impulses per revolution are obtained with this type of engine, remarkable steadiness of operation results,

GAS ENGINE PRINCIPLE AND PRACTICE.

the number of impulses received by the piston being similar in number to those of the steam engine.

One of the notable features of this engine is the large sizes

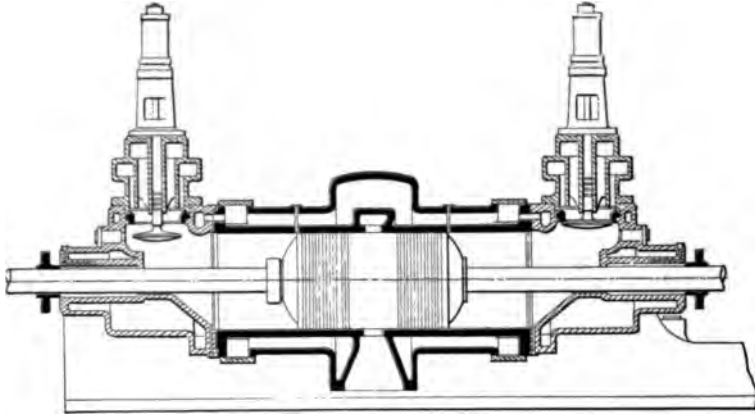


Fig. 12.

in which it is manufactured, being made up to 2,000 horse power with two motor cylinders placed side by side, the

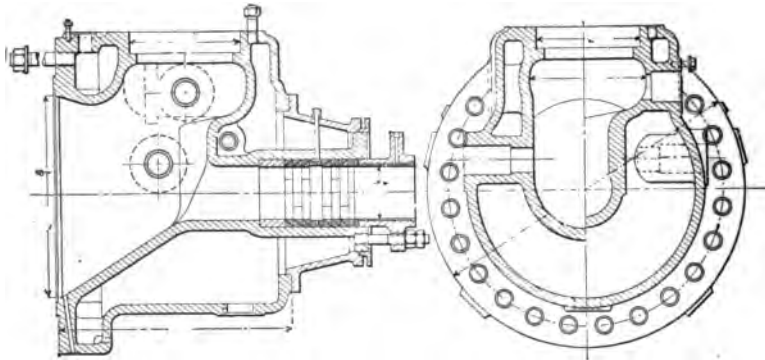


Fig. 13.

cranks operating at 90° , the auxiliary air and gas pumps being actuated from crank discs attached to each end of the crank shaft.

VARIOUS TYPES OF ENGINES.

The *Oechelhauser gas engine* shown at Figs. 14, 15, is built by the Berlin Anhalt Machine Company. It will be noted that the engine consists of a three-throw crank, a very long cylinder with two pistons and a separate pump cylinder L at the back. In the working cylinder the two pistons are turned back to back, so that the combustion space is between them. The front piston, P, is connected to the central throw of the crank at 1: the back piston, V, to the crosshead K, and to the two outer throws 2 and 3, of the crank. The piston rod of the gas and air pump, L, also connects to the crosshead K. The air pump L, is double acting, the front end handling only air for scavenging—i. e., for cleaning out the working cylinder after each working stroke. The rear end handles gas and air.

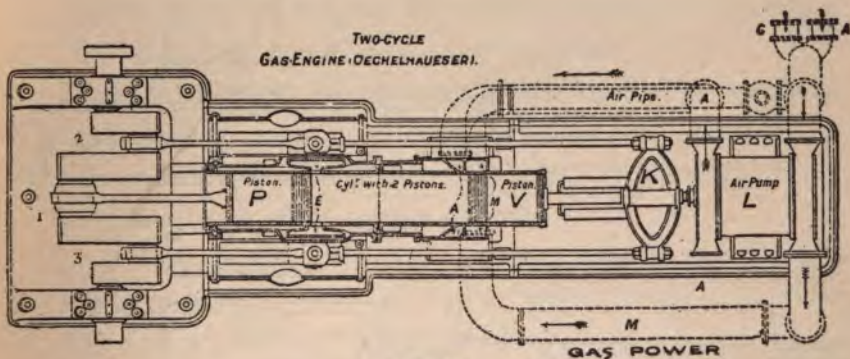


Fig. 14.

Referring to Fig. 14 we see the engine just completing the working stroke. The front piston P, has uncovered the exhaust ports at E, allowing the exhaust gases to escape while the pressure in the cylinder drops to that of the atmosphere. At this point the rear piston V, has passed over the port M, through which the previously compressed air for cleaning

GAS ENGINE PRINCIPLE AND PRACTICE.

flows and fills the cylinder with fresh air, driving the burnt gases remaining in the cylinder out at E.

A slight further movement uncovers the port A, through which a rich mixture of gas and air enters. This mixture combined with the air in the cylinder forms the explosive charge, so that when the pistons return the inlet and exhaust ports are successively covered and the charge is then compressed to about 150 pounds to the square inch and fired.

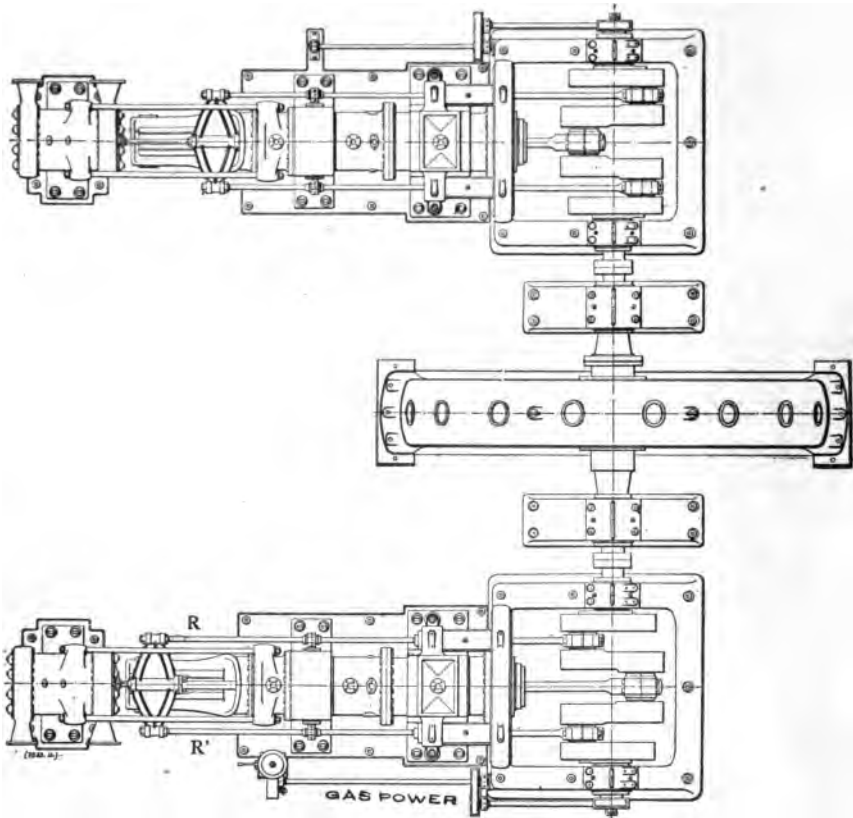


Fig. 15.

This engine has a motor cylinder open at each end fitted with two pistons which work in opposite directions, the air

VARIOUS TYPES OF ENGINES.

and gas before admission through M into the motor cylinder being compressed in the auxiliary pump placed behind the power cylinder.

The exhaust gases are emitted through the ports uncovered by the forward piston.

The charges of air and gas enter through the double row of ports in the side of the cylinder uncovered by the back piston, the scavenging air entering the cylinder first, followed by the mixture of gas and air.

It will be noted that the back piston is operated from the two side cranks, placed at 180° from the center crank, and guide rods and connecting rods.

Among the mechanical advantages for this design are the almost complete balancing of the reciprocating parts. The rapid expansion of the gases due to the moving apart of two pistons after ignition secures high operative economy and a minimum loss of heat to the cylinder walls.

The design has other strong points, viz.: The enormous strains on the frames of large gas engines are eliminated and the cylinder can be inspected without the removal of the crosshead and other moving parts.

This drawing, which is of a 1,000 horse power Oechelhauser engine direct coupled to an alternator does not show the details of the governor, nor the piping which connects the air pump with the engine. The two side rods R and R, are of very small diameter in proportion to their length because in transmitting the power of the rear cylinder these rods are always in tension, both for compression and explosion.

The Nurnberg gas engine is shown at Fig. 16. This engine is of the four-cycle type double-acting. It will be seen

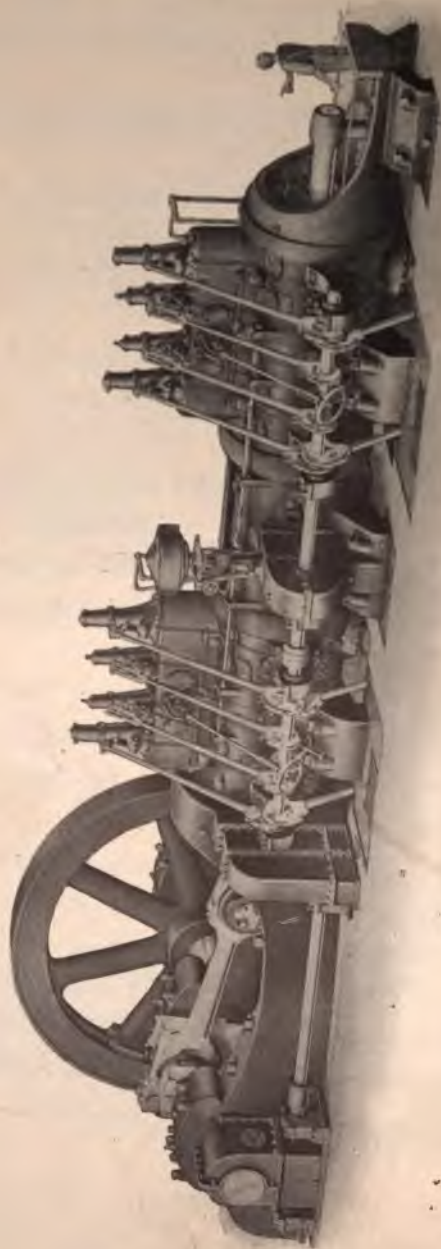


Fig. 16.

VARIOUS TYPES OF ENGINES.

from the illustration that the cylinders are placed tandem. Fig. 17 shows a sectional view of the cylinder of this engine and also shows the design of the air inlet and exhaust valves. As the explosion takes place on each side of the pistons with the tandem type of engine two explosions are received per

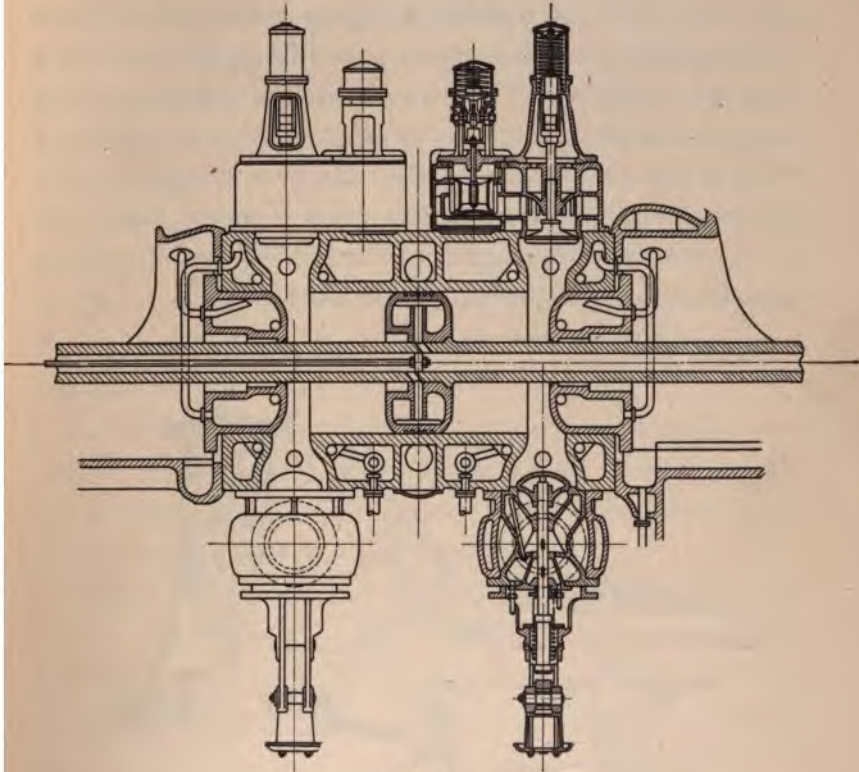


Fig. 17.

revolution of the crank pin. As will be noted from the illustration, Fig. 16, the valves are all positively operated, each end of the cylinder being provided with three separate valves, that is, the air and mixing valve, the gas valve and the exhaust valve.

GAS ENGINE PRINCIPLE AND PRACTICE.

One of the advantages claimed for this engine is the accessibility of all valves and pistons. The design is such that the piston in the forward cylinder can be easily withdrawn in the front end while the piston in the second cylinder can be easily withdrawn from the back, the cylinder heads being merely loosened from their studs and can then be slipped along the piston rod without deranging the metallic packing in the stuffing boxes, the connecting rod being first uncoupled from the crosshead and raised so as to clear the piston when being withdrawn from the cylinder. As the cam shaft which is operated in the regular way by gearing from the crank shaft and by intermediate gears is placed above the floor level this arrangement renders all the valve moving apparatus within easy reach of the attendant.

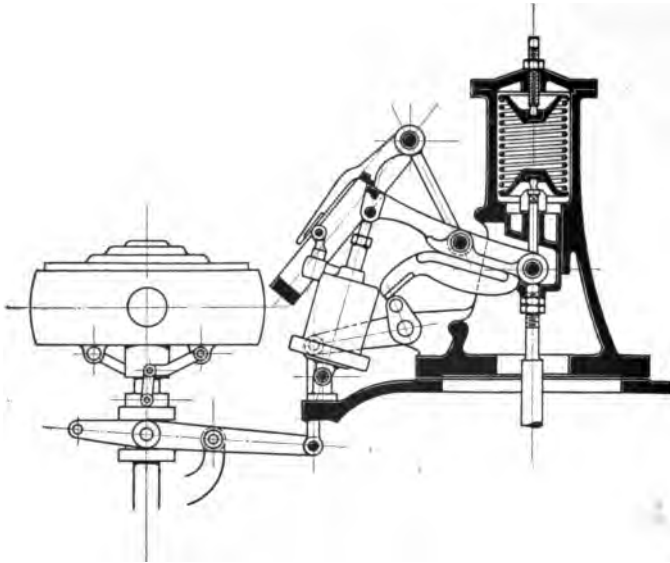


Fig. 18.

The regulation of speed is controlled by a powerful centrifugal governor which acts upon the gas valves only as

VARIOUS TYPES OF ENGINES.

shown in Fig. 18 and is arranged to regulate the opening of the valves and also the point in the suction stroke at which the gas valves commence to open. Thus the volume drawn into the cylinder remains constant. The pressure of compression does not vary, but the amount of gas admitted, is varied in accordance with the load and allows wide fluctuations in load with remarkably close governing effect. As will be seen from the sectional view, the cylinders, piston, cylinder heads and piston rod as well as the exhaust valves and their housings are all water-jacketted. The pistons are provided with tail rods and are supported by cross heads at both ends and consequently do not rest on the cylinder walls. The piston rod stuffing boxes are provided with metallic packing which is arranged to move up and down or sidewise with the rod which is a very important feature of this type of engine.

It will be noted from the illustration that the valves are operated, not by cams, but by eccentrics which result in their quiet running. The engine is started by compressed air in the usual way with large engines.

Koerting four-cycle.—A four-cycle single acting type of engine which in Europe has met with great success, is the Koerting, shown at Fig. 19 and in section at Fig. 20. The chief features of this engine are the mixing valve and the water cooled projection in the cylinder.

The mixing valve is a double seated heavy valve inserted in the air and gas inlet passage to cylinder, it is lifted from its seat by the slight vacuum caused by the outstroke of the piston in the cylinder. This valve is arranged so as to split up the stream of incoming gas and thoroughly mix it with the incoming air. The gas supply is regulated by valve set

GAS ENGINE PRINCIPLE AND PRACTICE.

by hand, being adjusted only to suit the different kinds of gases used. The water cooled projection in the cylinder is a specially designed internal water jacket as shown in Fig. 20. It consists of water cooled tongue projecting into

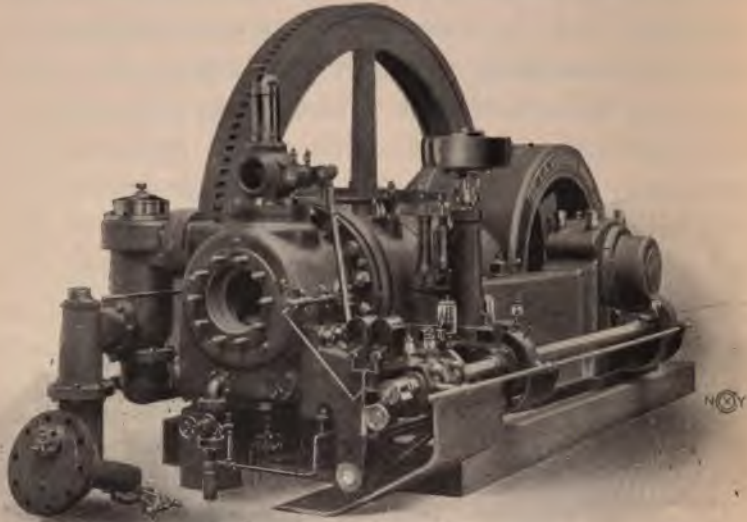
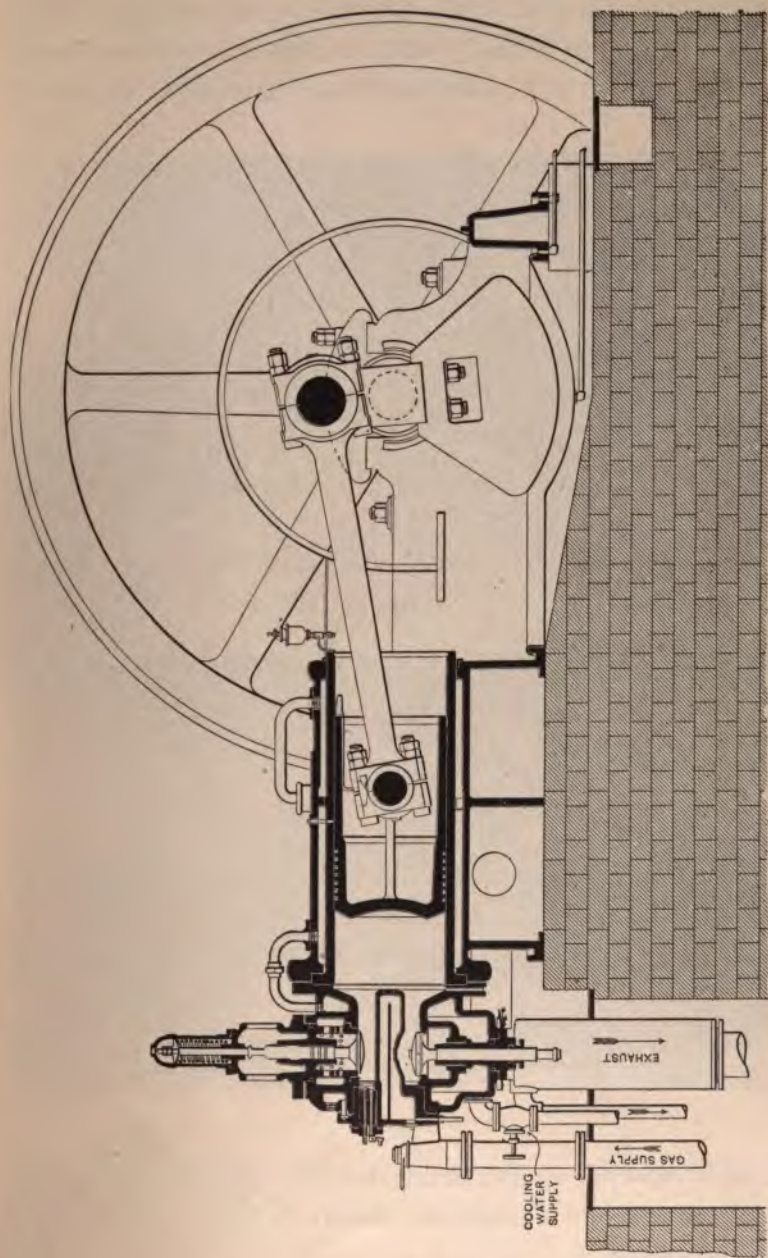


Fig. 19.

the combustion space and is effective by allowing greater cooled surface in contact with the heated gases than is the case in the engine of ordinary design, thus higher compression without pre-ignition can be obtained and consequent high thermal efficiency with this engine is attained. This projection has flange attached to it which is bolted to the back end of the cylinder, and can be easily removed or changed as may be required with various conditions requiring increased or decreased cooling effect.

The speed of the engine is regulated by powerful centrifugal governor acting on a balanced butterfly valve, arranged

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GAS ENGINE PRINCIPLE AND PRACTICE.

to vary the quantity of mixture entering the cylinder. The operation of which can be easily understood from reference to Fig. 21 in which the full load diagram is shown in

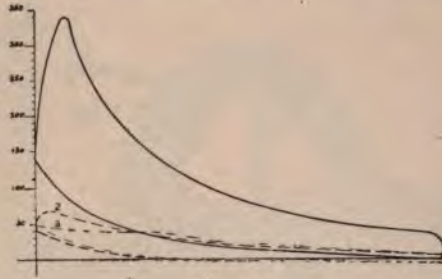


Fig. 21.

full line the dotted lines showing the impulse obtained at light or no load.

Westinghouse Horizontal Four-Cycle Double Acting Type.—In Figs. 22, 23, is shown the Westinghouse hori-

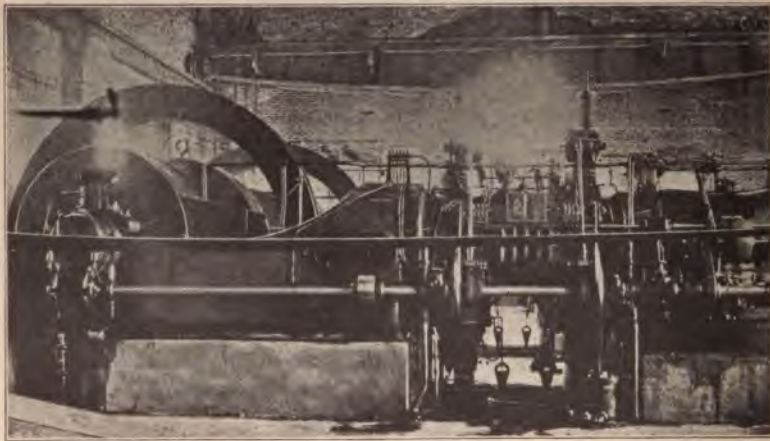


Fig. 22.

zontal four-cycle double acting tandem cylinder gas engine, which is made in sizes from 500 H. P. up to 3,000 H. P. By the tandem arrangement of cylinders, as shown, one im-

VARIOUS TYPES OF ENGINES.

pulse is obtained on each forward and backward stroke, the resulting effort at the crank pin being similar to that of a single cylinder double acting steam engine.

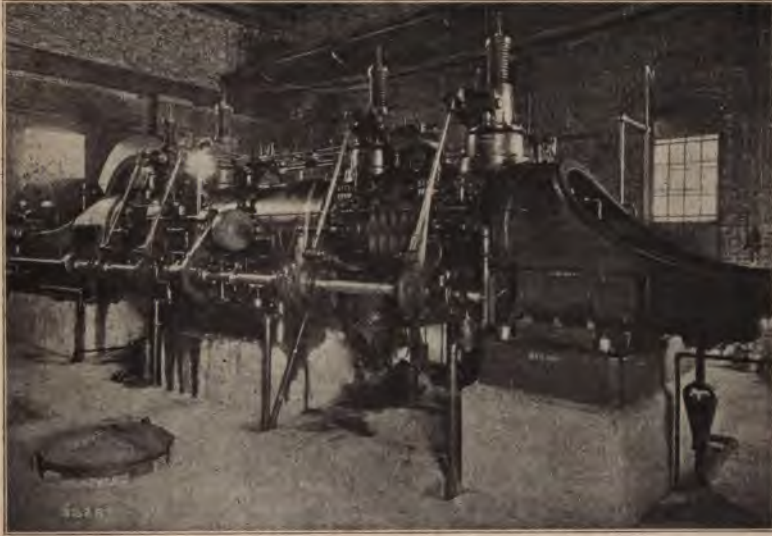


Fig. 23.

The illustration shows a 500 H. P. engine, which has cylinders 21 inches in diameter by 30 inches stroke and



Fig. 24.

runs at a speed of 150 r. p. m. Figs. 24, 25, show indicator cards taken at full load and with lighter spring from this engine.

GAS ENGINE PRINCIPLE AND PRACTICE.

It will be noted that all moving parts of the engine are above the floor level, which is advantageous inasmuch as such parts are thus rendered most accessible. It has been the aim of the designer of this engine to make it as near "fool-proof" and as near automatic in operation as possible. To this end the cooling water supply and the lubrication have been arranged so that inattention will not result in damage.

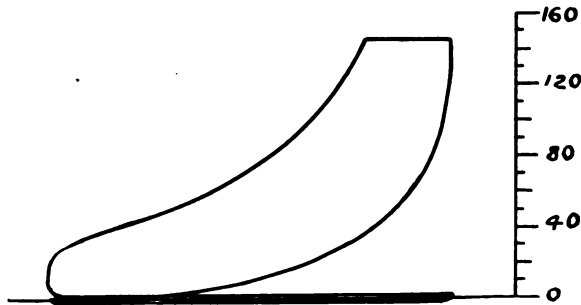


Fig. 25.

On reference to the illustration it will be seen that the cylinders are supported on center and rear frames respectively, the main frame only being anchored to the foundation. By this means freedom is allowed necessary for expansion and contraction of engine body. The crank shaft is of solid forged steel, approximately 18 inches in diameter at maximum and has an overhung steel crank disc, forced on with taper fit. The crank pin is cast integral with the disc, which, to insure homogeneous metal, is cast under pressure head. The bearings are made in three parts, are easily removed by simply jacking up the shafts, they are cored for water circulation, if necessary.

A special feature of this engine is a split jacket band, which closes the opening left in the outer cylinder jacket

VARIOUS TYPES OF ENGINES.

walls. This arrangement allows of adjustment of strains, due to shrinkage and differential expansion between cylinder and jacket walls, and allows cleaning to be readily performed.

The valve chambers are placed at each end of the cylinder structure and are of vertical design. These chambers can be easily removed when it is necessary to clean the interior of the cylinder, which obviates the necessity of removing the cylinder head. The piston is made without internal ribs and permanently mounted on piston rod. The nickel steel piston rods have a hole drilled through the center for water duct. The piston floats in the cylinder, being supported at each end by the piston rods, the weight of the pistons being entirely carried by the piston rods; thus, the piston rings only are in contact with the cylinder, reducing friction and wear. Each piston has four segmented cast iron rings, equipped with flat springs. An important feature of all double-acting gas engines is the piston rod gland. In this engine by the use of segmental metallic packing rings arranged in series, suitable packing is effected without causing undue friction, the gland being allowed to float so as to absorb slight variations in alignment. The design allows of the packing being easily removed.

The air and exhaust valves are of the poppet type, all steel, seated by springs and are mounted in removable bonnets.

The inlet valve is employed both for admission and as a governor valve. The mixture in proper proportions of gas and air being made when they reach the interior of this valve. Two distinct operations are performed by this valve, first the vertical motion which opens the air and gas ports, sec-

only a rotative movement whereby the quantity of the mixture is admitted to the cylinder in accordance with the requirements of the load on the engine. Butterfly valves in both gas and air ducts maintain proper ratio of air and gas, each valve is controlled by the governor. By this arrangement a somewhat richer mixture is obtained with very light loads thus insuring greater certainty of ignition.

The exhaust valves are operated by eccentrics in connection with a multiplying motion, thus allowing at first concentration of lifting force necessary against the heavy exhaust pressure, followed by rapid opening as soon as the valve has left its seat. Each valve is, of course, water-cooled. The lay-shaft, paralleling the engine's cylinders, operated by a two to one gear from the crank shaft operates air inlet and exhaust valves.

The governor is very sensitive in operation. This advantage is obtained by means of an oil relay system. A reciprocating piston under 40 to 50 lbs. pressure actually operates the valves, it is controlled by a small balance pilot valve which in turn is alone actuated by the governor; thus, a minimum amount of work only has to be overcome by it. Oil for the relay system is supplied by a small pump.

Two independent systems of ignition are supplied, first, being the hammer break or low tension type, and, second, the high tension system with jump spark, which are separate and complete at all points, the igniters being operated from a small auxiliary lay-shaft, parallel to the main shaft, suitable arrangements being made for advancing or retarding the timing of ignition. All igniter plugs are removable in one piece and any of them may be changed while the engine is running by simply cutting off the supply of gas to the end of

VARIOUS TYPES OF ENGINES.

the cylinder where the change is to be made and, at the same time, relieving the cylinder compression. Simultaneously, the other end of the cylinder can be retained in service. The cooling water is supplied by individual inlet and outlet, so that the temperature of each water-cooled part can be easily ascertained which is a very important feature.

The method of starting is by compressed air at 200 lbs. pressure. On engine lay-shaft are arranged four cams, operating small poppet valves, which, on starting, will inject compressed air, properly timed. No manual adjustment of the valve mechanism is necessary. After the first complete gaseous mixture is drawn into the cylinder in proper proportion and with succeeding ignitions, the engine comes up to speed; then, the compressed air system is shut off by the pressure of compression, operating against special check valves. By this arrangement only one man is required for starting the engine. The oiling devices are automatic, each end of the cylinder being equipped with a sight-feed plunger pump operated from an eccentric. The lubricant is handled by the circulating pump and filter, each moving part being thoroughly flushed with lubricating oil.

The Crossley Engine is shown in section at Fig 26. The illustration is of a larger size engine, horizontal with the cylinders facing each other. It is single acting and of the four-cycle type. As will be seen from the illustration the cylinders are made with separate liners which are ribbed on the outer side so to increase the surface exposed to the cooling water. The piston is also water cooled, the water entering and leaving the piston through the flexible connections shown in the illustration. The cylinder head and exhaust valve chamber are made in separate castings. The exhaust valve is shown in Fig. 36.

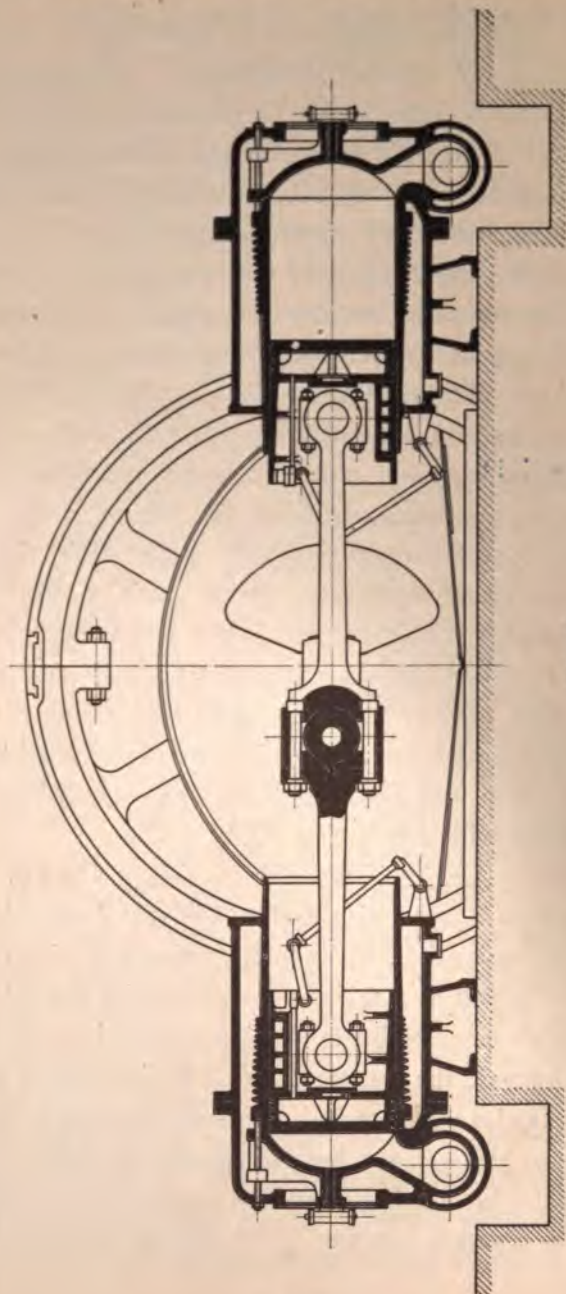


Fig. 26.

CHAPTER III

VALVES AND VALVE MOTIONS

The variations in design of internal combustion engines have been referred to in Chapter II and a comparison of engines of the different cycles has been made. Amongst the more important features of every engine is the design and arrangement of the air and exhaust valves, the fuel inlet valves, and mechanism actuating them.

TWO-CYCLE TYPE.

In the two-cycle engine (shown in Fig. 88) where the air or mixture is compressed in the crankchamber, the absence of all valves will be noted except that controlling air inlet to

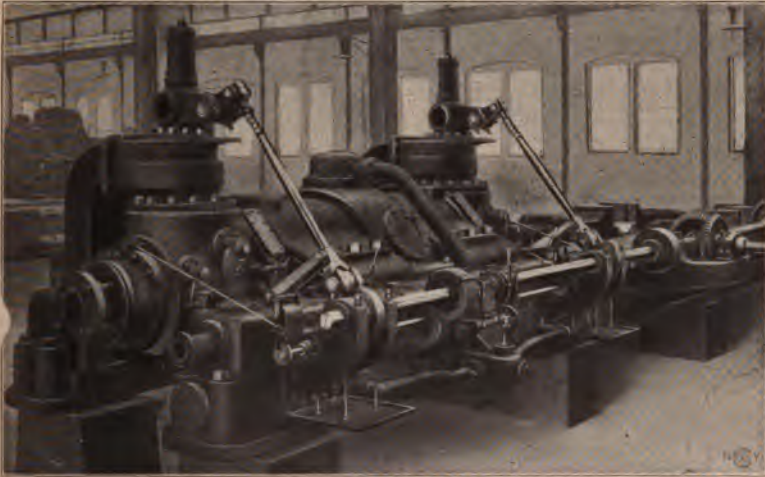


Fig. 27.

the crankchamber while in the two-cycle double-acting engine where the process of compression of the air and gas is

GAS ENGINE PRINCIPLE AND PRACTICE.

performed in auxiliary cylinders valves of the piston type are used. The inlet valves and cams being shown in Fig 27. In other two-cycle engines such as the Oechelhauser no air inlet valves are required in the motor cylinder. With the Koerting, the piston performs the function of the exhaust valve by uncovering the ports in the cylinder walls at the end of the combustion period the process of expulsion from the cylinder of the exhaust gases being completed by the rushing into the cylinder of the fresh charge of air under slight pressure from the auxiliary air pump or cylinder.

FOUR-CYCLE TYPE.

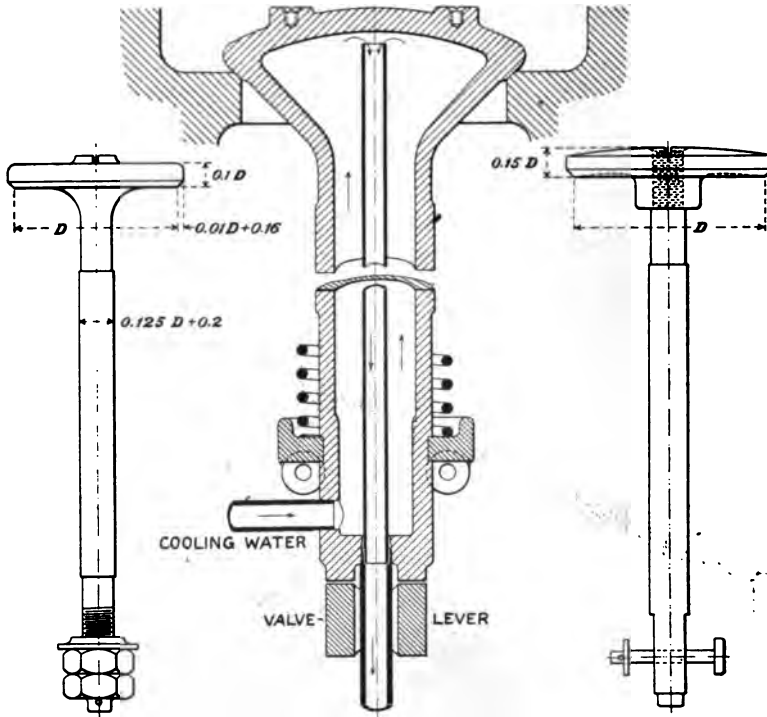


Fig. 28.

In the various four-cycle engines the arrangement of valves again is very different. In the early type engines a

VALVES AND VALVE MOTIONS.

slide valve at the back end of the cylinder was used which allowed the proper inlet and outlet to and from the cylinder as well as the timing of ignition by flame. This design is now entirely out of date and the valves of the four-cycle engine are practically all of the poppet type as shown in Fig. 28. In the earlier engines the pressure of explosion and consequently the temperature obtaining in the cylinder were very much lower than those found in present gas engines, which have also been very much increased in size and thus the higher pressures and temperatures which the valves have to withstand have required most careful design to obtain the best results. Water circulation through the exhaust valve in large four-cycle engines is now standard practice and balancing of the valve as shown in Fig. 36 is considered most ad-

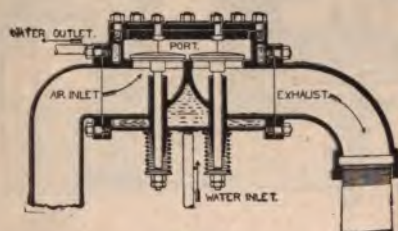


Fig. 29.

vantageous in that this decreases considerably the work to be performed in opening the valve against the pressure existing at the end of the expansion stroke when the exhaust valve commences to open.

LOCATION OF VALVES.

Figs. 29, 30, 31, 34, show various designs of valves and the different methods of placing them in relation to the cylinder. These are:

GAS ENGINE PRINCIPLE AND PRACTICE.

a. Both air and exhaust valve placed in a separate valve chamber attached to the cylinder and both being placed in a vertical position.

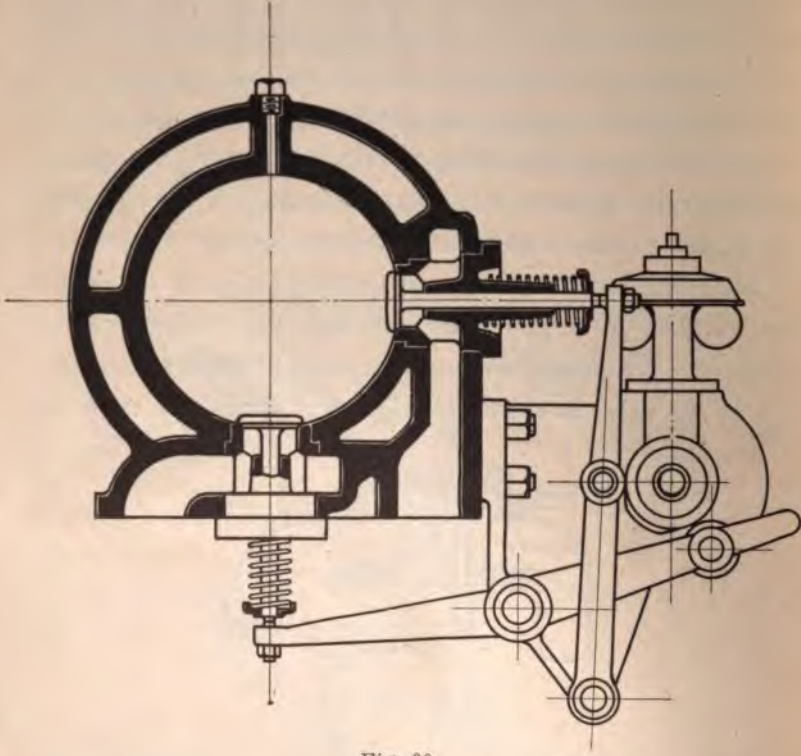


Fig. 30.

b. The exhaust valve placed on one side of the cylinder and the air valve on the other, the exhaust valve being vertical and the air valve horizontal.

c. Both valves placed in the cylinder head and both being horizontal with the horizontal type of engine or being placed vertically in the vertical type.

d. The air valve placed on the top of the cylinder at the back end with the exhaust valve underneath it, the air valve

VALVES AND VALVE MOTIONS.

opening downwards, the exhaust valve upwards, both vertical.

e. The air valve placed on the top or side of the cylinder head operated automatically being controlled by light spring, the exhaust valve being positively operated by cam.

The proper arrangement and design of valves requires that they must be so placed as to reduce as much as possible

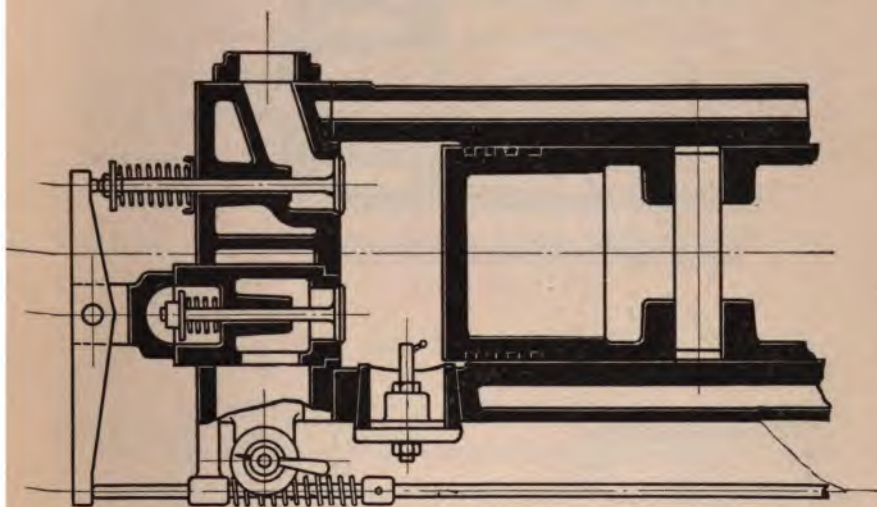


Fig. 31.

the clearance in the valve casing and passages to the cylinder and to allow free ingress and egress of the gases to and from the cylinder. Further, the valves should be as accessible as possible so that they can be easily taken out for examination, regrinding or repairs.

The valves operating vertically are considered the best design as the wear of the stem will be less than with the valve placed horizontally. The vertical type valve will not be liable to wear as is the case when placed horizontally and will continue to fall concentrically on its seat. The proper

GAS ENGINE PRINCIPLE AND PRACTICE.

design of valves is also important to avoid choking of the gases on entering the cylinder. The inlet valve should be designed so that the mean flow of gases does not exceed 120 ft. per second, while the exhaust valve should allow the mean velocity of the exhaust gases not to be greater than 80 ft. per second assuming the exhaust to be discharged at atmospheric pressure. These speeds, however, are frequently greater in larger engines and high speed small engines.

The speed of opening and closing of the valves and the amount of lift is resultant upon the cams which must be of suitable formation to give proper opening and closing, but should be so designed as to avoid undue noise in operation.

The valves are closed by means of springs as shown in Fig. 30. The seat of the valve is more generally made conically

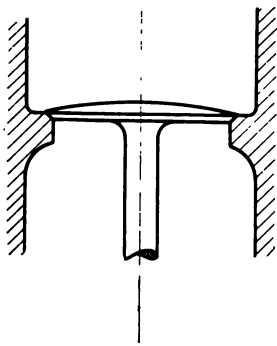


Fig. 32.

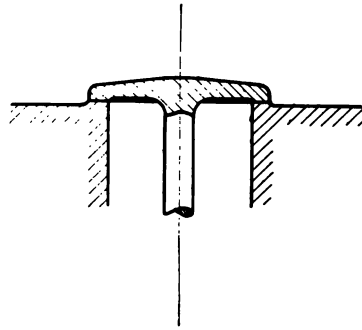


Fig. 33.

as shown in Fig. 32. Some inlet valves are made flat faced as shown in Fig. 33, the former being preferred.

The lift of the valve should not be more than one-fourth its diameter. The lift of the valves in slow speed engines will be found to be somewhat greater than that of high speed engines. The dimensions for the various parts of the valves

VALVES AND VALVE MOTIONS.

are shown in Fig. 28, which are taken from valves in actual use.

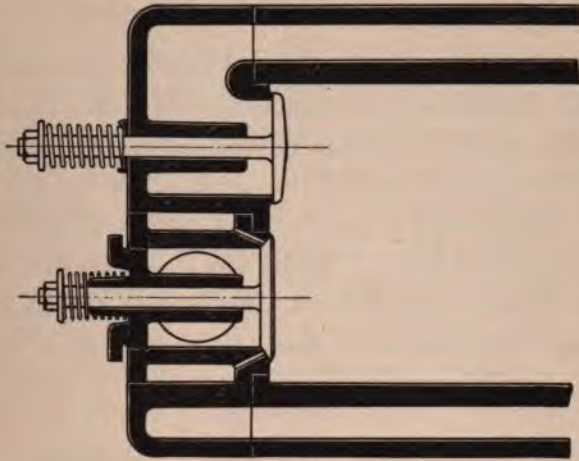


Fig. 34.

VALVE SPRINGS.

The closing springs for valves opened by cam should allow about a pound mean pressure per square inch of valve. The spring controlling the automatic air valve which is opened by vacuum in the cylinder caused by the movement of the piston, shown in Fig. 31, should be less than three-fourths pound pressure per square inch of valve, but should be sufficient to properly close the valve, but not great enough to choke the incoming air.

Fig. 35a shows an average setting of valves for the four-cycle engine. These settings will be found to vary with different makes of engines and will also vary as the speed of the engine varies.

The following may be taken as average conditions considering different types of engines:

GAS ENGINE PRINCIPLE AND PRACTICE.

Air inlet opens from five to eight degrees after the crankpin has passed the inner dead centre and closes from five to twenty degrees after the crankpin has passed the outer dead centre.

Exhaust opening from 30° to 60° before the crank reaches the outer dead centre and closes from on centre to 15° after.

In some types of engines the exhaust valve remains open slightly longer and other valve settings are as shown at b. Where timing valve is used in connection with ignition tube, this is opened about 25° before the crank reaches the dead centre. Where a gas valve is used, this will open at the inner dead centre and will close about 15° before the crank reaches the outer dead centre.

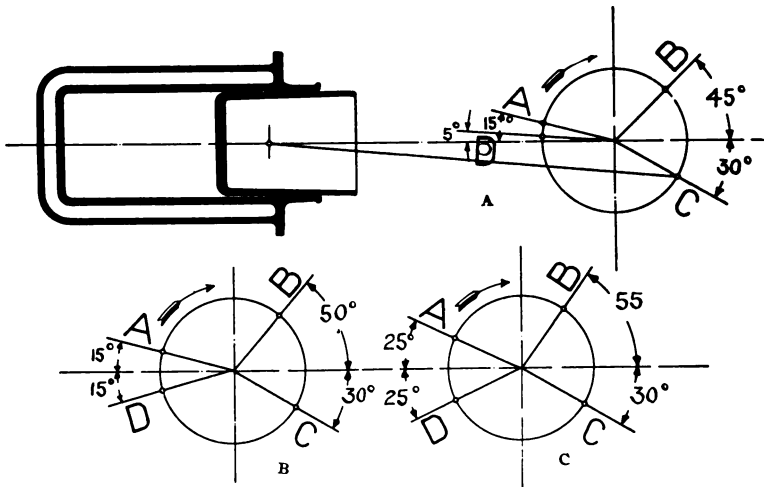


Fig. 35.

Valve Settings.—A, exhaust valve closes; B, exhaust opens; C, air valve closes; D, air opens.

SCAVENGING.

In some engines the momentum of the gases passing through the exhaust pipe is made to scavenge the cylinder,

VALVES AND VALVE MOTIONS.

that is, assist in getting rid of the products of combustion and to obtain this result the air valve is opened more than 15° before the crank reaches the dead centre somewhat similar to the setting shown at c, Fig. 35. The exhaust valve remains open till after the air valve has opened, thus allowing the momentum of the gases in the exhaust pipe to form a slight vacuum, drawing out from the cylinder the burnt gases. This is particularly advantageous when burning gases of low calorific value where high compression is necessary and this arrangement tends to obviate the possibility of premature explosions, allowing more rapid and more complete combustion and consequently greater economy of fuel.

The proper design and dimensions of valves and passages can be tested by means of the indicator with a low pressure spring as described in Chapter V; choking of the air and exhaust can then readily be detected.

WATER COOLED VALVES.

As previously mentioned with gas engines of 150 H. P. and over with a single cylinder in consequence of the very high temperatures existing it has been found necessary to cool the exhaust valve by means of water circulation. In Fig. 28 a valve of this description is shown. The water circulates around the inside of the valve maintaining it at the proper temperature, eliminating expansion and contraction, thus insuring the valve remaining tight on its seat, the inlet valve in engines of large size being also water cooled.

BALANCED VALVE.

As the terminal pressure in the cylinder when the exhaust valve is opened is often as high as 35 lbs. per square inch, it can readily be understood that considerable work has to be

GAS ENGINE PRINCIPLE AND PRACTICE.

performed to lift the valve against this pressure and to obviate this strain a balanced valve as shown in Fig. 36 has been

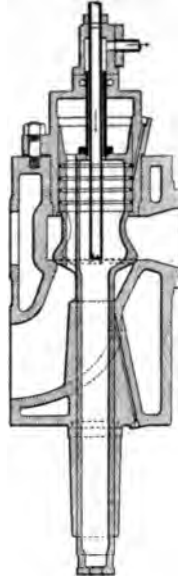


Fig. 36.

designed. This arrangement equalizes the pressure on the valve and accordingly it is operated without exerting the strain required with the ordinary type of valve.

REVERSING DIRECTION OF ROTATION.

To reverse the setting of the valves so that the direction of rotation of the crankpin is reversed it is necessary with the four-cycle engine to change the location of the cams and consequently the periods of opening and closing as shown in Fig. 35. The timing of the electric igniter being also reversed so that it operates in the reverse relation to the inner dead centre of the crankpin as when working in the opposite direction. The same remarks apply also to the alteration of the timing valve used with the tube igniter.

VALVES AND VALVE MOTIONS.

When reversing the two-cycle single acting engine no change is necessary except with the igniter and with the two-

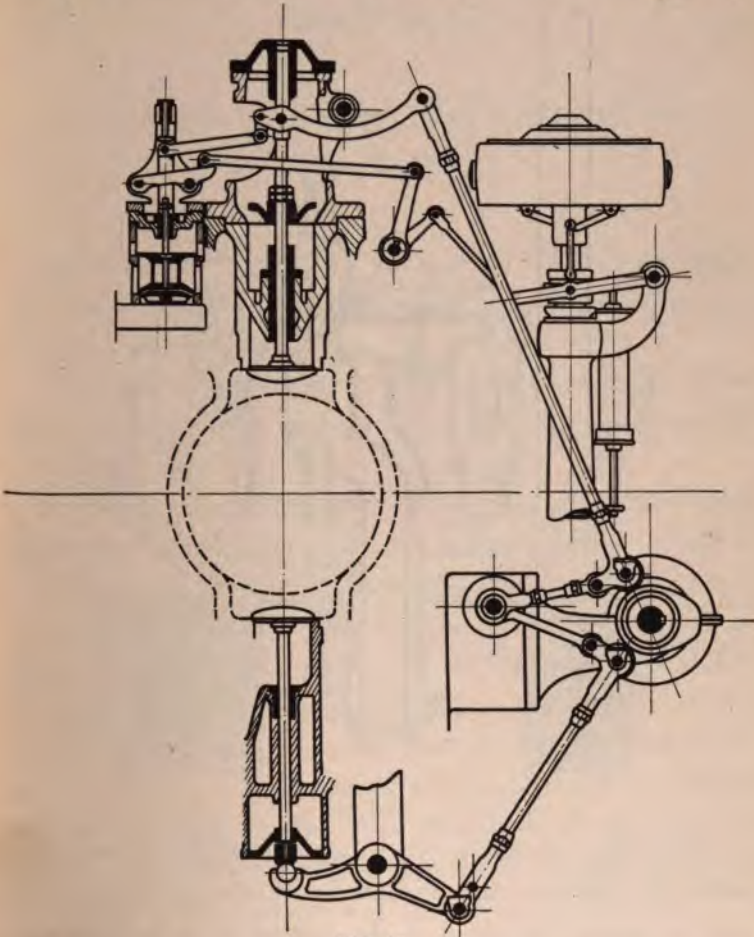


Fig. 37.

cycle double acting engine all that is necessary to change is the igniting apparatus.

VALVE MOTION.

As the movement of the valves is reciprocating and as they are operated from a revolving part of the engine a

GAS ENGINE PRINCIPLE AND PRACTICE.

mechanism as shown in Figs. 30, 31, 37, 38, is employed to obtain the proper action of the valves.

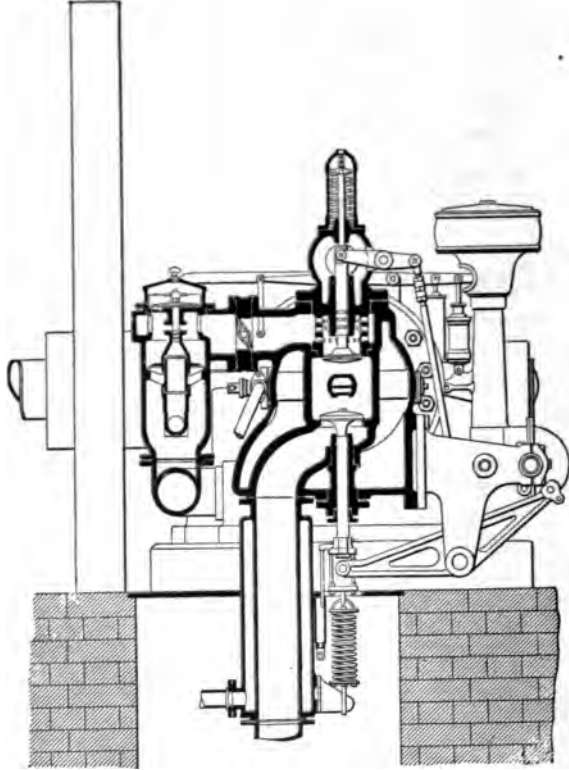


Fig. 38.

With the four-cycle type the valves are opened every other revolution of the crankshaft. Consequently gearing is used to reduce the speed of the cam shaft to half the speed of the crank shaft. Worm or skew gearing is most commonly used for this purpose.

Rotary valves having rotary motion have been introduced in some engines, but owing to difficulty in maintaining the surfaces of the valve they have not yet been much used and will not be described.

CHAPTER IV

GOVERNORS; IGNITERS; SELF-STARTERS AND OTHER DETAILS.

An important feature of an internal combustion engine and one that frequently makes the engine a success or a failure, is the governor.

The function of the governor is, to vary the power of the engine in accordance with the load it has to overcome and accordingly regulate the speed.

There are two causes of variation of speed in an internal combustion engine; first, that due to the variation in angular velocity of the crank pin, brought about by the fluctuating pressures in the cylinder on the piston and the inertia and momentum of the reciprocating parts, which is regulated by the flywheel and balancing parts on the crankshaft. This is known as "cyclical" variation, that is, the variation within one revolution or cycle and is allowed to vary in different engines according to the work they have to do. For instance, in engines operating direct current generators this variation is allowable if not exceeding one-sixtieth. For engines operating shafting or other machinery where variation in angular velocity is not so important, a variation of one-twentieth is frequently allowed, while for engines operating alternating current generators in parallel, a variation not exceeding one-hundredth is required. In some cases even less variation is necessary.

GAS ENGINE PRINCIPLE AND PRACTICE.

To fulfill these requirements with the four-cycle single-acting engine of the single-cylinder type exceedingly heavy flywheels would be necessary, as well as carefully designed governing gear, and therefore for work, such as operating alternators in parallel, the type of engine having two or more cylinders, single-acting or of the four-cycle double-acting or two-cycle double-acting in which the greatest possible frequency of impulse occurs, is preferred, thus obviating the necessity of excessively heavy flywheels.

The second variation in speed, which is controlled by the governor, is the variation between different cycles, thus when the engine is heavily loaded and the load is quickly removed, it is the function of the governor to vary the impulse so that in the cycle following, the power developed is that only required to overcome the lighter load. This variation in speed with fairly even load in different engines varies from one to two and one-half per cent. while this variation is frequently as much as five per cent. when the load varies from full to one-quarter load, but the regulation in modern large gas engines designed for electric drive requires closer variation.

METHODS OF GOVERNING.

There are different methods of governing gas engines. With the older and smaller type a device as shown in Fig. 39, and known as the "hit-and-miss" type was frequently employed. With this method of governing, Fig. 40 shows the pressure resulting with the full charge and when the governor operates, the result obtained is shown by the indicator card in Fig. 41. The name "hit-and-miss" is derived from the method of operation of this device as shown in the illustration, that is, it is arranged either to give the full charge of

GOVERNORS; IGNITERS; SELF-STARTERS.

fuel to the cylinder or the whole charge is cut out. There are different methods of applying this "hit-and-miss" gov-

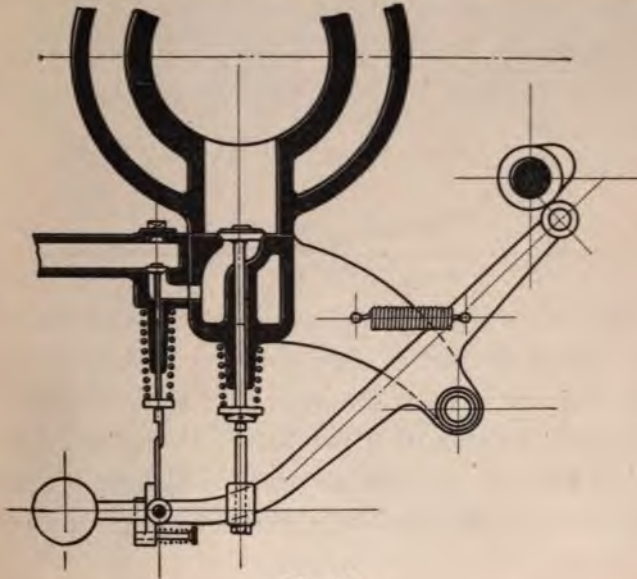


Fig. 39.

ernor to various engines. In some cases it operates on the exhaust valve, holding this valve open and preventing the suction of a charge of fuel into the cylinder when no impulse



Fig. 40.

is required. In other cases it is arranged to operate on the gas admission valve. In this case it opens the gas valve when

GAS ENGINE PRINCIPLE AND PRACTICE.

the full charge is required and when no impulse is necessary to overcome the load, the governor lever misses the stem of the valve and it remains closed.

It can readily be understood that with this method of governing, variation in speed with the full impulse or no impulse occurs.



Fig. 41.

With modern engines requiring steadier speed, the admission of gas or mixture to the cylinder is varied and in that case an indicator card as shown in Fig. 42 is obtained from which it will be seen, that the M. E. P. in the cylinder is varied by the action of the governor and is not entirely cut out as shown in the previous illustrations, Figs. 40 and 41.

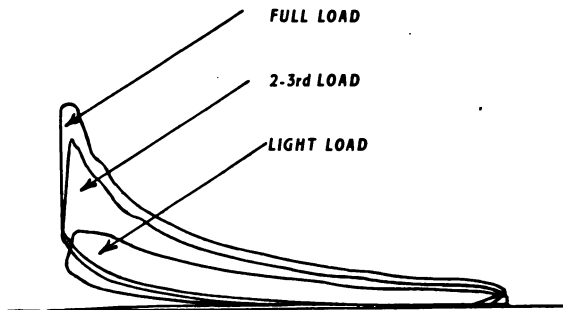


Fig. 42.

The methods of governing in recent years have shown great improvements with the development of the gas engine in larger units. In commercial use it is obvious that the most effective governor is that which allows the minimum change in fuel economy when the load is changed from full load to light load, that is, it is the aim of the designer to arrange the governor and the method of governing so that the ther-

GOVERNORS; IGNITERS; SELF-STARTERS.

mal efficiency of the engine will be the greatest possible under all conditions. Three systems of governing have been developed in larger gas engines of modern manufacture. These may be described as follows:

(a) The quantity of the mixture entering the cylinder is constant under all conditions, but the quality of this mixture is changed.

(b) The quantity of the mixture is varied, but the quality of the mixture remains unchanged.

(c) The quantity and quality of the mixture is varied.

COMPARISON OF METHODS OF GOVERNING.

These different systems have various advantages and disadvantages. As stated in a previous chapter, the aim of the designers has been to increase the compression before ignition in the gas engine cylinder. With the first named method of governing, the compression remains constant at all loads. With the second named system, where the quantity of fuel admitted is varied, the compression at light loads is naturally reduced. Systems of governing are now in use, particularly in German engines, to overcome these defects. One maker has arranged the method of governing so that both the quantity and quality of mixture is varied, but with light loads the timing of the ignition is made to occur earlier, thus obviating the possibility of missed explosions at light loads.

Another system of governing is that which allows the cutting off of the current from the electric igniter. This device, however, is not much in use at the present time.

GOVERNING OF KEROSENE AND FUEL OIL ENGINES.

The methods employed in these engines may be classified as follows:

GAS ENGINE PRINCIPLE AND PRACTICE.

(a) Fuel by-pass,—the governor operating on a valve inserted in the oil supply pipe, which is opened as the speed is increased and allows part or all of the fuel to be by-passed back to the fuel tank instead of entering the vaporizer or cylinder, as shown in Fig. 43.



Fig. 43.

(b) By holding open the exhaust valve. In this system there is no suction into the cylinder from the fuel supply and the result obtained is similar to that previously described with the "hit-and-miss" governor.

(c) The regulation of both fuel and air supply.

(d) Varying fuel supply. The governor acting directly on the pump varying the stroke to suit the varying load.

Most of the oil engines now in use employ the first named method of governing; i. e., the amount of air drawn into the cylinder is in excess of that required to support combustion under all conditions, the amount of fuel entering the vapor-

GOVERNORS; IGNITERS; SELF-STARTERS.

izing chamber or cylinder being varied by the governor by means of a by-pass, as described, or by allowing the governor to act directly on the fuel supply pump, varying its stroke.

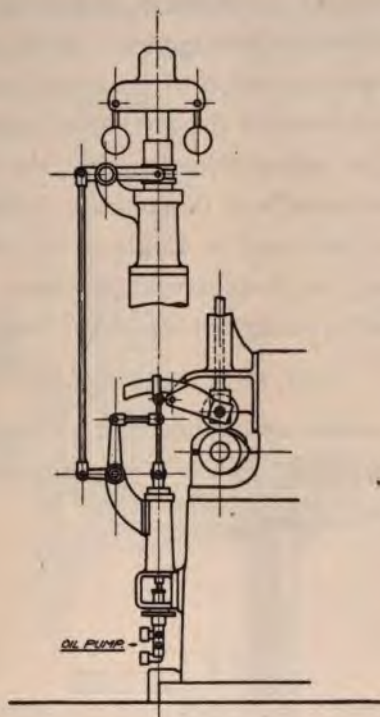


Fig. 44.

The principle in either case is similar, i. e., the variation of the fuel supply only. Simplicity in operation is secured by this arrangement.

GOVERNING OF GASOLINE ENGINES.

With this type of engine the governor either operates on a valve inserted in the fuel supply pipe, allowing part only of the carburetted gasoline to enter the cylinder, or the

GAS ENGINE PRINCIPLE AND PRACTICE.

governor is arranged to operate on the exhaust valve holding it open as explained on page 71.

IGNITION.

There is no part of the internal combustion engine which gives more trouble than the igniter. It is essential, therefore, for the proper operation of the engine that the attendant thoroughly understand the method of operation of this apparatus. In gas and gasoline engines, the electric igniter is used almost universally in this country, while the hot tube igniter has been preferred in England for the smaller gas engines on account of simplicity in operation. The electric igniter is now there coming into use more largely.

HOT TUBE IGNITION.

This igniter consists of a tube about 4" long, inserted into the wall of the cylinder. When in operation, it is maintained

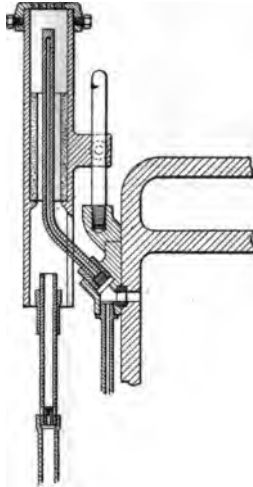


Fig. 45.

at a red hot temperature by an external heater. The gases in the cylinder during the period of compression are forced

GOVERNORS; IGNITERS; SELF-STARTERS.

into this heated tube and there become ignited. This igniter without timing valve is shown in Fig. 45. The timing valve as shown in Fig. 46 is used by some makers, especially in the larger engines, so as to ensure the proper timing of the operation. This valve is mechanically operated and thus, being only opened at the correct period for ignition, pre-ignition is

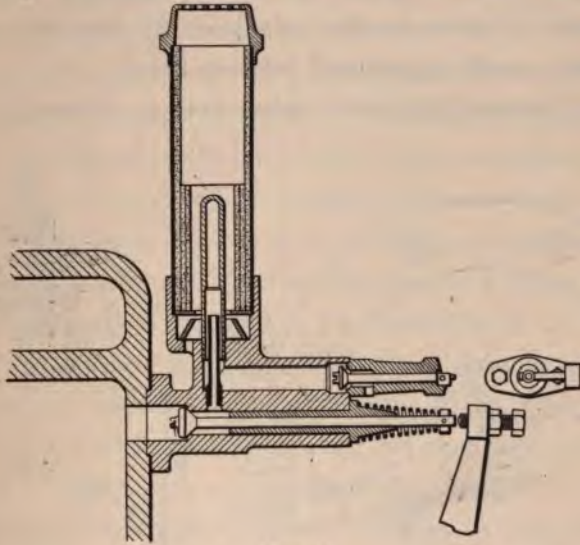


Fig. 46.

impossible, which can occur with the tube having no timing valves. The tubes are now made of porcelain or other suitable alloy, which is very much more durable than wrought iron, formerly used. The accompanying illustration shows the methods of attaching them to the cylinder.

ELECTRIC IGNITERS, MAKE AND BREAK.

There are two forms of electric igniter most largely in use, known as the "make and break" type and the "jump-spark" type. The former type is more generally in use with

GAS ENGINE PRINCIPLE AND PRACTICE.

large gas engines; it is considered more reliable than the other type but it has the disadvantage of moving mechanical details inside the cylinder. This igniter is shown in Fig. 47.

It consists of one stationary well insulated terminal inside the cylinder, with one movable or mechanically operated terminal H also placed inside the cylinder. The electric circuit is broken by the separation of these two terminals, thus a spark is produced between them.

Fig. 47 shows this igniter when used in connection with

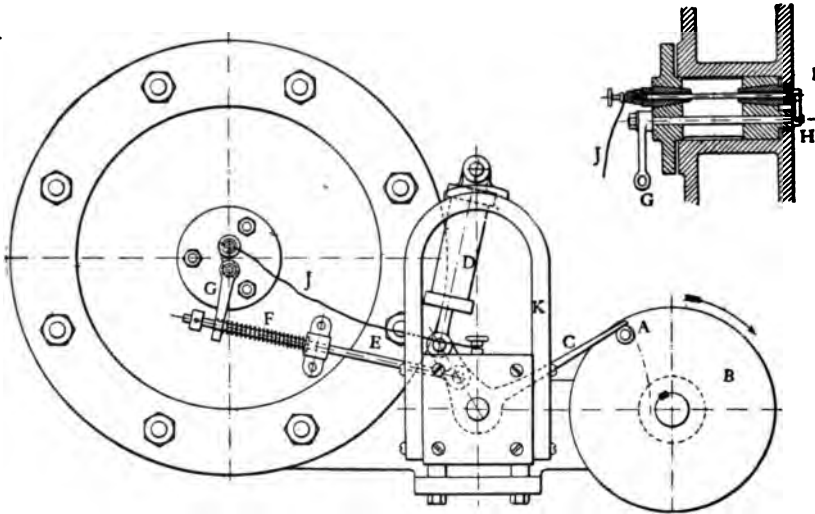


Fig. 47.

a magneto generator which is most frequently employed to furnish the electric current, with this type of igniter in the place of battery or continuous running dynamo.

With the magneto generator of this type the electric current is generated by the quick movement of the armature caused by the movement of the arm C suitably actuated from the cam shaft or other moving part of the engine and

GOVERNORS; IGNITERS; SELF-STARTERS.

the quick action of the spring D. The magneto is a very simple device, having stationary steel magnetos K and a cast iron armature with coil imbedded in the same. Its action is as follows:

The arm C is raised by the roller A attached to the disk B shown keyed to the engine camshaft. The spring D in Fig. 47 is compressed. When the arm is released the armature has a quick downward movement due to the spring D which movement produces a strong electric current. This current passes through connection J to insulated igniter point and through the movable electrode G back to magneto generator. The movement of the armature lever by heavy spring allows the collar on the rod E to hit the arm attached to the movable electrode, thus the two electrodes are separated and a spark passes between them. The principle of this igniter is to break the electric current and only at the moment when the armature conductors are cutting the greatest amount of magnetic lines of force, thus causing the most powerful spark between the electrodes when suddenly divided.

The fundamental principle of electricity is, that if a wire carrying current and wound around iron thus producing a magnetic field be broken, the induction of the magnets intensifies the pressure of the current at that moment and by it increases the intensity and length of the spark between the separated electrodes.

In the "make and break" type it is usual to employ eight to ten volts and from three to five amperes derived from a battery or a dynamo and a primary coil consisting of a number of turns of insulated wire wound about an iron core. The current passes through this coil to the terminals within the cylinder, or, as already stated, the current is taken from a

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magneto-generator in which case the volts are increased about 100 volts and the amperes decreased to one-half or one ampere.

THE GOODSON IGNITER.

An igniting outfit made by the Goodson Ignition Company, Providence, R. I., is shown at Figs. 48, 49, 50. It consists of a magneto somewhat similar to that already described but

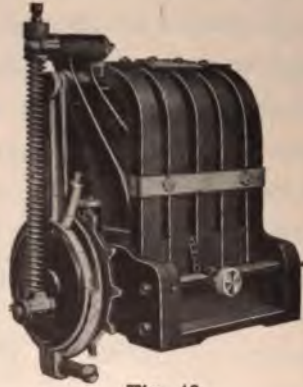


Fig. 48.

operated by sprocket chain from the engine camshaft. The armature in operation is made to revolve by a spring device



Fig. 49.



Fig. 50.

for half a revolution at a speed independent of the speed of the engine and which is sufficient to generate the necessary current for proper ignition. The same amount of current is

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furnished the igniter under all conditions. The timing of ignition can easily be altered by simply tilting the magnetos to one side. No batteries are required when starting the engine. The make and break igniter plug (see Fig. 51) operates electrically therefore no mechanisms to separate the electrodes are required which simplifies the arrangement and renders this igniter very reliable in operation.

JUMP SPARK IGNITER.

The "jump spark" igniter plug which is made in many different designs and which has been so much used on high speed gasoline engines, and automobile engines, is shown in Fig. 52. This type possesses the advantage of mechanical

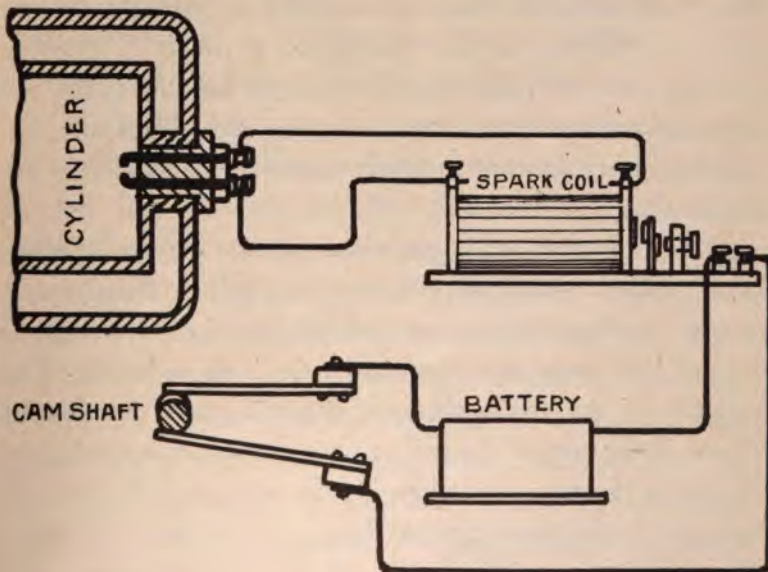


Fig. 51.

simplicity owing to the terminals in the cylinder being fixed without any moving mechanical details whatever inside the

cylinder. This allows facility of observation and adjustment while the engine is in motion and further, the trouble caused by wear in the mechanically operated igniter with this type is entirely eliminated.



Fig. 52.

With the jump-spark igniter, there are two methods of operating it, but both methods require an induction coil, a vibrator being used in the one case but not in the other. Where the induction coil is used without the vibrator a single spark is produced at the opening of a circuit in primary winding. As the single spark is more or less unreliable, the induction coil with the vibrator is preferred and in this case a series of sparks that virtually form an intense flame are produced.

The jump-spark coil, sometimes known as the "Rhumkorff" coil, is simply a transformer used to transform a current of comparatively low voltage and high amperage to one of low amperage and extremely high voltage. The strength of the spark obtained depends upon the amount of iron in the core of the coil and the number of convolutions of wire in the primary and secondary helices of the coil. A jump-spark coil suitably made should give between the terminal in the air a spark of one-half to five-eighths-inch. To produce this satisfactorily the coils transform a current of four to six volts to that of 5,000 to 6,000 volts or even more, which current is necessary to jump across

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the terminals divided by that distance. This spark is of sufficient temperature to form a spark across the terminals when placed in the cylinder $1/32$ to $1/16$ -inch apart. With engines of very high compression, higher voltage than that already named is sometimes recommended and is obtained by increasing the size of the coil. The jump-spark coil with vibrator consists of a soft iron core surrounded by two or more layers of No. 16 or No. 18 copper wire carefully insulated, known as the primary coil. Highly insulated from it and enclosing this primary coil is a second coil consisting of thousands of turns of No. 36 copper wire carefully insulated, being silk covered, each separate layer being well insulated from the preceding layer. These two coils with the iron core are enclosed within a suitable box or casing which allows one end of the iron core to project a short distance from the case. This box is then filled with melted wax to exclude moisture. In front of the projecting iron core attached to the casing is placed a vibrator which consists of a soft iron armature attached to a steel spring suitably supported so that the armature may vibrate in front of the iron core. Attached to the steel spring that supports the armature is a platinum contact piece, in line with and above this platinum contact piece is secured a platinum pointed adjusting screw supported separately from the armature. The object of the vibrator is to give a rapid interruption of the current passing through the primary coil and by this means to produce a secondary current of high tension in the secondary coil and thus a succession of sparks is secured at the electrodes which forms a flame sufficient to insure ignition. With a hammer blow type of vibrator a platinum contact piece is fixed upon a spring supported from the armature but

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so placed that the armature in its movement will strike the spring and separate the points of contact very rapidly with a sudden blow thus disrupting the primary circuit. The more rapidly this circuit is broken the greater the efficiency of the coil.

With this type of vibrator the armature moves an appreciable distance before the contact parts are separated, during this movement of the armature the primary current has more time to thoroughly magnetize the iron core and thus increasing pressure in the induced current and a higher potential results. All vibrators that have the contact piece fixed to the spring carrying the armature break the primary circuit at the moment the two contacts meet and thus the current has not sufficient time to magnetize thoroughly the iron core and therefore the current induced in the secondary coil is not as powerful as the other type.

The timing of the electric spark is caused by a movement of a part of the engine which closes the electric circuit from the battery or dynamo passing through the primary coil, and the retarding or hastening of the spark is effected by alteration of this cam or other part of the engine which is used to close the circuit.

IGNITER TROUBLES AND REMEDIES.

The electric igniter frequently causes trouble in the operation of an engine and when it is not operating properly, careful inspection of it is required to ascertain the cause of imperfect working. With the make and break type of igniter the movable electrode may seize in the bearing of the pin, which passes through the wall of the cylinder, and thus the two electrodes inside the cylinder are prevented from coming

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properly in contact. Cleaning and proper lubrication of this pin will remedy this trouble. Sometimes the breaking of the wire connection will prevent proper sparking or the connecting parts may become unscrewed or, with vibration, become loose and thus, contact being broken, will occasion improper working. In other cases grit or dirt collecting between the electrodes will not allow them to come together but careful inspection should enable the operator to ascertain and remedy the improper working of this type.

With the jump-spark frequently a run down or weak battery will be the cause of poor sparking, which is insufficient to ignite the charge. In other cases a short-circuiting of the current either by moisture in the plug or by poor insulation will prevent proper operation. The strength of the battery can be tested only properly with ampere meter; each individual cell should not read less than 3 or 4 amperes after being connected to ampere meter for few seconds (good battery will read from 8 to 12 amperes). In the absence of ampere meter, the strength of the battery can be determined by the force of the vibrator, or by disconnecting one wire from the plug and holding about one-fourth to one-eighth of an inch away from the binding post and the spark should jump that distance. This will prove that the battery is strong enough for proper working. Then the plug can be taken out of place in the cylinder and being placed on a part of the cylinder with the timing arrangement turned by hand a spark should be obtained sufficient to jump across the electrodes. If there is no spark then the circuit is taking place through imperfect insulation or other causes. In this case, if the battery is in proper working order, a new plug or properly insulated plug

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should be exchanged for the defective one. In many cases trouble is caused by bridging over of the terminals by carbonaceous matter, which makes good conducting substance for high pressure currents and causes short circuiting, which will effectively prevent sparking. In this instance, of course, cleaning or replacing with new plug is necessary to secure proper operation.

SELF-STARTING DEVICES.

The starting of gas engines up to about 30 H. P. is a comparatively easy operation. It simply requires the turning of the flywheel by hand after the proper adjustments to ensure fuel supply to the cylinder have been made, the igniter, if electric, having been suitably adjusted for starting and the exhaust cam moved so as to allow lower pressure of compression to be obtained in the cylinder until sufficient speed is developed to allow the momentum of the flywheels to overcome the full compression pressure.

Where tube igniter is used instead of electric or (as is the case with most oil engines) where the vaporizer has to be heated this must have proper attention also before attempting to put flywheels in motion.

With the gas engine of larger size (instead of being put in motion by hand as in the smaller sizes) it is first operated by compressed air supplied from an air receiver which is charged to a pressure of 100 to 200 pounds by an auxiliary compressor operated by electric motor or small gas engine. Thus in starting large engines which are equipped by all makers with proper starting valve arrangements it is first necessary to see that the crank pin is in proper position for starting and that the fuel supply is correct, that igniter is

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ready for operation and then simply manipulate the levers controlling the air supply. As soon as the compressed air enters the cylinder the flywheels begin to revolve and after one or more impulses of compressed air, sufficient momentum is acquired to allow of the different processes of the regular cycle of operations taking place. With an engine having more than two cylinders compressed air enters the one cylinder only, fuel being supplied and ignition taking place immediately after the first revolution in the other cylinder or cylinders according to the design of the engine. It is necessary that the air tank be of sufficient capacity to furnish the volume of air necessary for two or more impulses.

Another means of starting large gas engines is to simply turn the flywheel for two or three revolutions by means of an auxiliary motor, the compression pressure in the cylinder being reduced until ignition occurs when the full compression takes place and the regular cycle of operations follows.

GASOLINE ENGINES.

A simple self-starting device used on gas and gasoline engines is, that made by the Fairbanks, Morse Co. In this arrangement a charge of gaseous mixture is forced by means of a hand pump into the cylinder where it is ignited by a detonator or electric igniter and thus gives the first impulse to the piston the momentum derived being sufficient to cause the flywheels to revolve until the regular cycle of operations commences.

CHAPTER V.

TESTING.

Use of the Indicator and Brake—Representative Indicator Cards—Defects Shown by Indicator

The testing of internal combustion engines is most important and requires careful consideration.

Tests on the smaller engines up to about 100 H. P. are easily performed by the manufacturer before shipment from the factory. On the larger engines economy tests are frequently postponed until after installation on account of the expense of setting the engine up and making all necessary connections. Tests are made to ascertain some or all of the following:

- (a) The power developed.
- (b) The thermal efficiency; that is, the fuel or B. T. U.'s consumed per actual or per indicated H. P. per hour.
- (c) The speed regulation with even and varying loads.
- (d) The mechanical efficiency; that is, the loss of power by friction of the engine.
- (e) Other losses, such as the loss of heat to cooling water and exhaust.
- (f) The quiet and proper operation of engine at varying loads.
- (g) Proper operation of the valves, etc.

BRAKE OR ACTUAL HORSE POWER.

The power developed is measured by means of a Prony

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brake as shown in Figs. 53, 55, applied to the engine flywheel or pulley.

The power developed with brake as shown in Fig 55 is measured as follows:

$$\text{Brake H. P.} = \frac{W \times C \times N}{33000}$$

Where—

W=Net load in pounds.

C=Circumference of wheel in feet.

N=Revolutions per minute.

For instance, an engine running at 250 revolutions per minute has 50 lbs. on the brake, the circumference of the wheel being 12.5 feet.

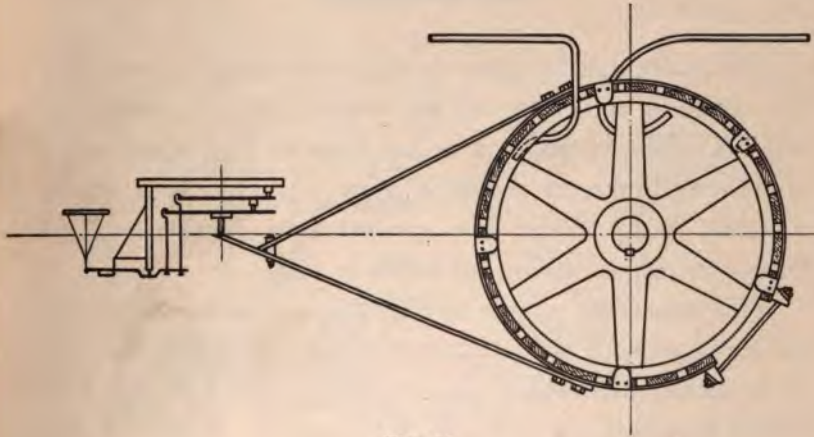


Fig. 53.

$$\text{B. H. P.} = \frac{50 \times 250 \times 12.5}{33000} = 4.73.$$

The diameter of the flywheel should be measured at the centre line of the rope. As the friction of the brake on the flywheel quickly heats the wheels of larger diameter in order

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to avoid the danger present with the flywheels overheated water cooled wheels, as shown in Fig. 53, should be used.

The power developed with brake as shown in Fig. 53 is ascertained as follows:

$$\text{Brake H. P.} = 2R \times \pi \times l \times Q \times n.$$

Where—

n = Revolutions per minute.

$$\pi = 3.1416.$$

l = Distance in ft. from centre of shaft to point where lever is in contact with scale.

Q = Weight in pounds on scale + weight of brake apparatus.

R = Radius of wheel in feet.

DYNAMOMETER.

The Alden dynamometer or absorption brake is an apparatus which is well adapted for testing internal combustion engines of the larger sizes or for those of high speed where the Prony brake, as shown in Figs. 53, 55, would not be suitable owing to the heat generated by friction and the inconvenience of cooling the brake by water.

This apparatus, shown in Fig. 54, consists of a cast iron casing in which a circular cast iron disc revolves. This disc is furnished with radial grooves and is keyed to the shaft which transmits the power to be absorbed. A pair of thin copper plates are fastened to the housing so as to come in close contact with the sides of the revolving disc. The apparatus is equipped with two systems of piping; one system for distributing the lubricating oil on the surfaces of the copper plates so as to insure efficient lubrication, and the other system of piping for furnishing the water under pressure

TESTING.

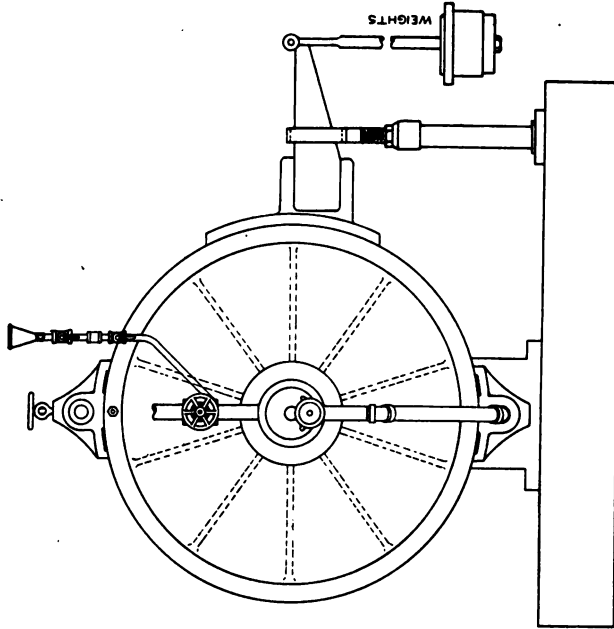
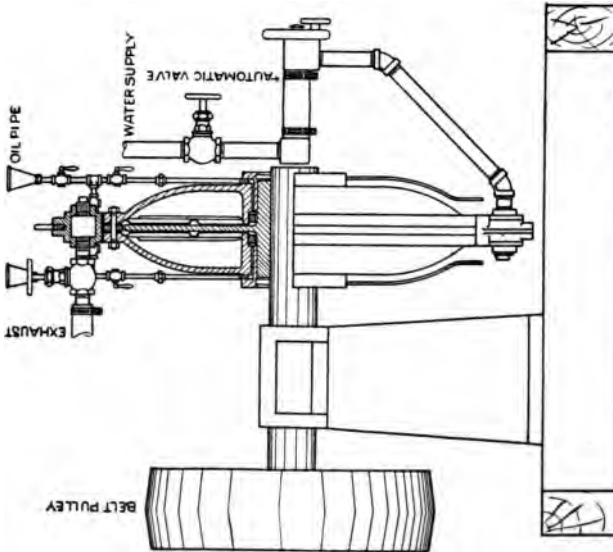


Fig. 54.



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through the chambers between the copper plates and the housing.

The power developed is calculated the same as when using the prony brake, shown at Fig. 53, being weighed as shown in the illustration, Fig. 54, by the placing of weights on the platform attached to the extended lever. When the dynamometer is in operation the water flows through the chambers in the casing and over the copper plates and tends to force the plates against the sides of the revolving disc. By this means the friction between the revolving disc and the copper plates is increased and tends to rotate the whole casing. The tendency to rotate is balanced by the weighing apparatus, the weights being adjusted to suit the power and thus the whole is kept in equilibrium.

The pressure of the water is regulated by automatic valve. This water supplies pressure which causes the friction and also carries off the heat evolved by that friction. The oil enters a chamber in which the disc revolves, near its centre, and is carried by centrifugal force along the radial grooves on the sides of the disc and is ejected through tubes outside on the casing.

The dynamometer can be mounted directly on the shaft or it can be operated by belt. It is made in various sizes, the largest yet made is designed to absorb 200 H. P. at 100 R. P. M.

The lubricating oil used should be a heavy cylinder oil and the water should have a steady pressure, preferably between 40 to 100 lbs.

ELECTRICAL MEASUREMENT OF POWER.

Frequently the power developed is measured by electrical instruments when the engine is operating a dynamo. In that

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case 746 watts represent 1 B. H. P. allowance being made for the losses in the dynamo the efficiency of which may vary from 80% to 93%, according to size and design of dynamo. The loss due to the belt or other power transmission being taken into account which may be from 5% to 10%.

FUEL MEASUREMENT.

The fuel or B. T. U.'s consumed per H. P. hour are measured, if gaseous, by meter; if liquid by weight and is arrived at by attaching fuel tank, as shown in Fig. 55, and taking the exact weight before and after test the difference being the amount consumed. With the producer plant the amount of fuel consumed is frequently measured by marking a point in the producer, poking the fire and filling with fuel to that point before the test is commenced; when the test is completed and the fuel consumed weighed, the fire is again poked and filling to the same point with fuel as before starting takes place. The speed regulation is tested by means of a speed counter or with an instrument known as a Tachometer.

With the gas engine the indicator is used to ascertain the proper timing of ignition in the cylinder, the proper setting of the valves, also to determine that proper combustion of the gases is taking place. The horse power developed can be computed from the gas engine indicator diagram, but the internal combustion engine is usually sold on a brake or actual horse power rating, that is, the rating is based upon the power actually developed by the brake at the flywheel or driving pulley; and consequently the usefulness of the indicator to determine the power with the gas engine is not so prominent as with the steam engine.

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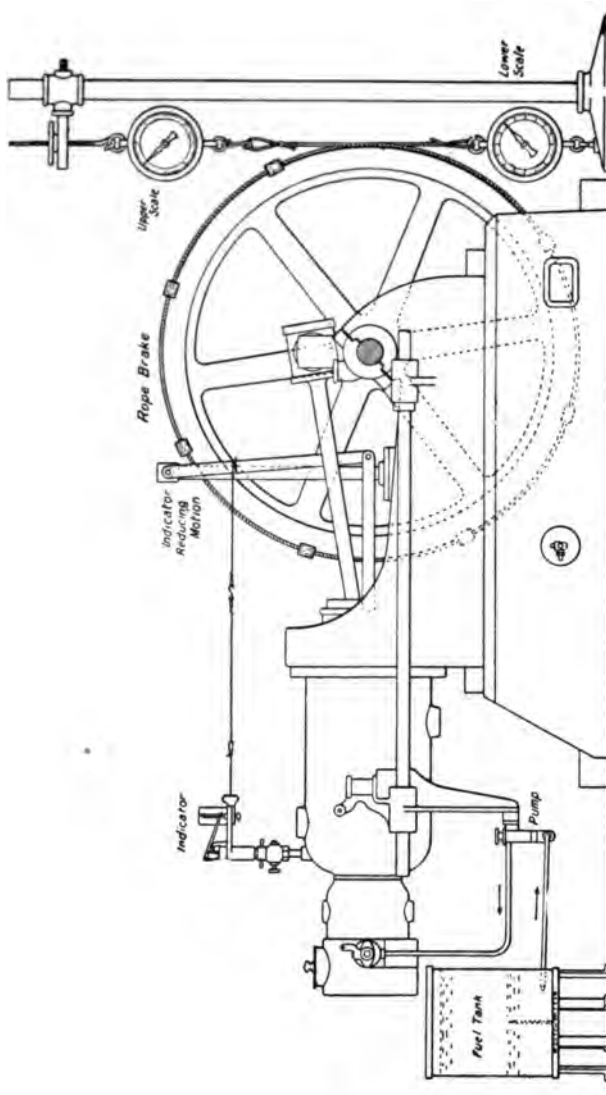


FIG. 55.

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The throttling of the air inlet to the cylinder or the choking of the exhaust outlet can also be detected from the diagram.

ELEMENTARY REMARKS.

An indicator diagram may be considered as a graphical representation of work performed. As a simple and brief illustration, in Fig. 56, take line OB to represent P —lbs. equiv-

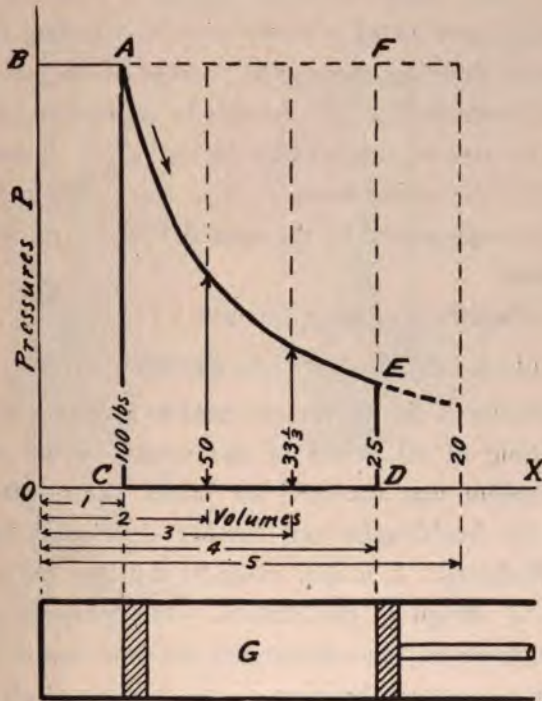


Fig. 56.

alent to a suitable scale and draw line $O X$ at right angles to $O B$ representing 1, the length of feet traveled by a piston if the pressure P remains constant while the piston moves from

A to F, a rectangular figure, AFDC, would be described, the work performed being $P \times L$.

Suppose a gaseous mixture enclosed in cylinder G, whose area is "a," the point A will represent the condition of such mixture as regards pressure and volume. Now with the volume increasing as the piston is moving from C to D, the pressure due to the burning of the gas and the expansion of same, the pressure will decrease as the volume increases, therefore the point, A, as the piston moves forward will describe a curve which would be similar to A E. To ascertain the work performed it is necessary to calculate the average pressures obtaining during the passage of the piston from C to D as shown in Fig. 56; let this be represented by p lbs. pressure, the area of the cylinder being "a" in square inches the length of the stroke being C D in feet. Then the work done will be represented by the area A E D C and is arrived at as follows:

$$\text{Work} = \text{pressure } p \times \text{area } a \times \text{length CD.}$$

DETAILED DESCRIPTION OF INDICATOR.

The indicator is the instrument used to ascertain the pressures obtaining at all points of the stroke in the cylinder. This instrument was invented by James Watt, afterwards improved by McNaught and further developed by Prof. Chas. B. Richards. It is now made by different makers with variations in design in the details. The purpose of each instrument, however, is to accomplish the same result, namely, to record the pressure obtaining in the cylinder at all periods of operation.

USE OF THE INDICATOR.

In order that the indicator diagrams may be thoroughly understood by those readers who are not familiar with such

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diagrams and with the use of the indicator, an elementary and detailed description of the indicator will first be presented.

Fig. 57 illustrates in sectional view a standard type of gas and steam engine indicator.

The piston, A, is made of tool steel and very accurately fitted to the cylinder, B, which for the gas engine indicator is made to equal the area of one-quarter of a square inch. The piston rod is made hollow for the sake of lightness, is

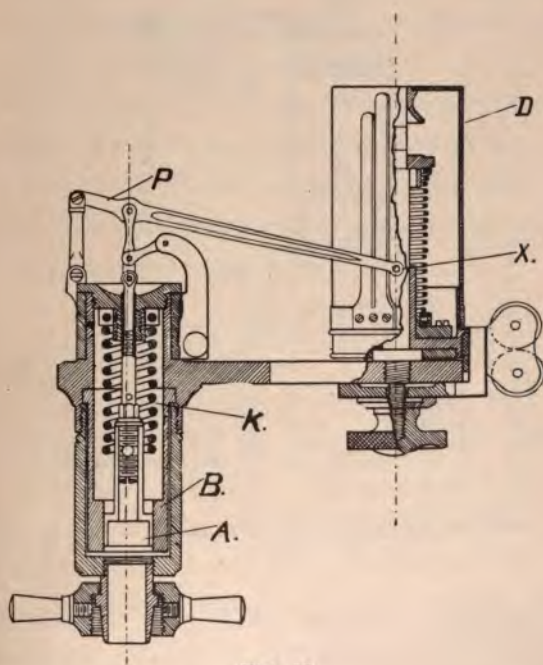


Fig. 57.

suitably connected to the piston at the lower end and has a swivel head, to which the pencil arm P is attached, connected to its upper end. The pencil arm is made to receive the pencil at X, the other end being attached to a simplified form of

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parallel motion allowing the movement of the pencil to be six times that of the movement of the piston and to be exactly parallel with it.

One of the most important parts of the indicator is the spring. In the indicator described, it will be seen that this is of unique design, being made in one piece, the lower end

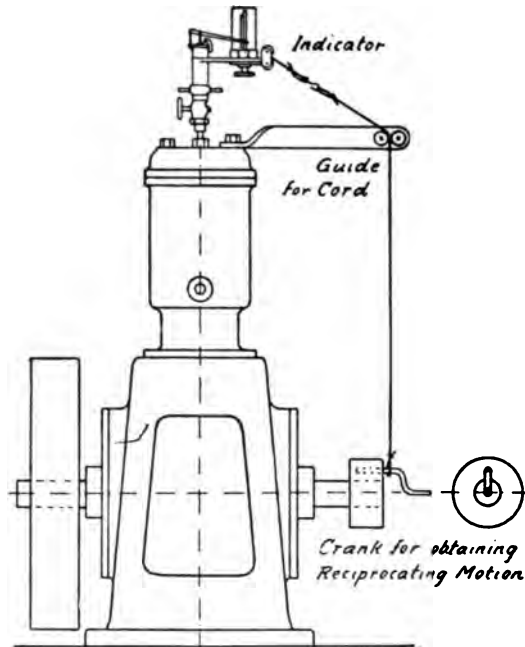


Fig. 58.

having a small ball attached, which when in place allows the spring flexibility in motion, thus ensuring freedom to the piston. The drum supporting the paper on which the record made by the vertical movement of the pencil is placed, is fitted with a groove for a cord and has placed inside it a spiral spring arranged to bring the drum back into position as the cord in the groove allows the movement. The motion

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of the cord attached to the reducing motion is controlled by the movement of the engine piston or other reciprocating part.

The function of the piston in the indicator when attached to the cylinder of the engine is to move upward as the pressure is created in the cylinder; the carefully designed and tested spring regulates this movement in direct accordance with the pressure, so that the pencil arm moved by the pressure of the piston indicates the exact pressure simultaneously existing in the engine cylinder, the vertical movement of this pencil arm being regulated exactly to equal a given scale by the spring to which it is calibrated.

The function of the revolving drum operated from a reciprocating part of engine by a reducing motion is to keep pace with the movement of the piston in the cylinder; thus the vertical movement of the pencil records on the paper at any instant the pressure existing in the cylinder.

INDICATOR REDUCING MOTION.

The method of attaching the indicator to the cylinder is shown in Fig. 55. The illustration portrays the Hornsby-Akroyd oil engine under test. The reducing motion consists simply of a rocker arm suitably attached to the piston and suspended from a rigid support as shown. It can be readily understood from the illustration how the stroke of the piston of the engine is reduced to suit the particular length of the indicator card placed around the revolving drum of the indicator.

There are various methods of reducing the motion of the engine piston, one of which is shown at Fig. 58. This consists of a bent arm placed in a disc attached to the engine

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crankshaft, the cord from the indicator drum when in operation being slipped on and off this device as required. Fig. 59 shows a reducing motion consisting of a short connecting rod actuated by a pin attached to end of crankshaft, the other end of connecting rod being attached to sliding bar to which the cord from the indicator is connected. Another and much

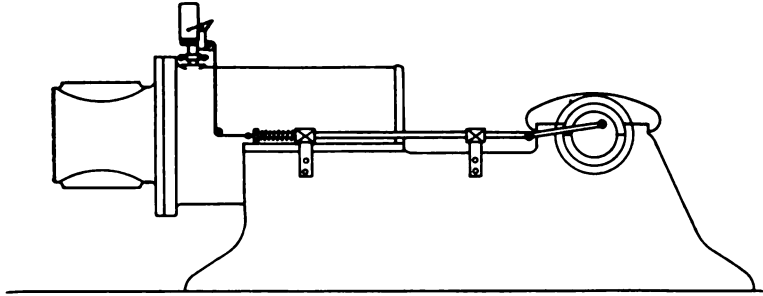


Fig. 59.

used reducing motion is that consisting of two wheels of different diameters, the smaller having the cord attached to the drum of the indicator around it, while the larger one is operated by a second cord from the engine crosshead, piston or other reciprocating part.

POSITION OF INDICATOR.

It will be seen from the illustration, Fig. 55, that the indicator is placed as near as possible to the engine cylinder and it is important that the connecting pipes used should not be less than one-half-inch diameter and should be short and direct.

In placing the indicator in position great care should be exercised that the paper drum is allowed to move freely to and fro under the pencil, and that the travel of the drum is not so great as to come in contact with the stops on the indi-

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cator at either end. If the indicator is not carefully adjusted various errors in the results obtained may be shown, and the record made is not a true representation of the performance of the gases in the cylinder.

The inertia of the piston and other moving parts of the indicator should be reduced to a minimum and for this reason they are made as light as possible. The joints of the reciprocating motion should not be loose nor have play, and further friction of such parts must also be eliminated as far as possible. The accuracy of the indicator spring should be beyond question and the recording pencil should be free from undue friction on the paper. The indicator cord should not be allowed to stretch, and in some cases, especially where the cord is of considerable length, it is best to use a thin steel wire to avoid stretching. Care should also be taken that the pipes or cock leading from the cylinder to the indicator be carefully blown out to avoid any burnt or charred oil and gritty matter coming in contact with the indicator piston.

TAKING INDICATOR CARDS.

With the indicator in position the atmospheric line, see Fig. 60, should be taken by connecting the cord from the reducing motion and allowing the pencil to record its position with no pressure being exerted in the indicator cylinder.

The proper size of the spring to be used is determined by the pressure to be contended with in the cylinder; for instance, if a pressure of 300 lbs. is to be encountered a 200-lb. spring would be suitable; that is, for each inch vertical movement of the pencil 200 lbs. would be represented and therefore with 300 lbs. maximum pressure the total vertical movement of the pencil would be $1\frac{1}{2}$ inches.

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Care must be taken that the spring is heavy enough, otherwise injury to the indicator may result from the pencil passing above the drum.

FOUR-CYCLE DIAGRAM.

An actual diagram taken from the four-cycle engine is shown at Fig. 60. It is often necessary to determine the

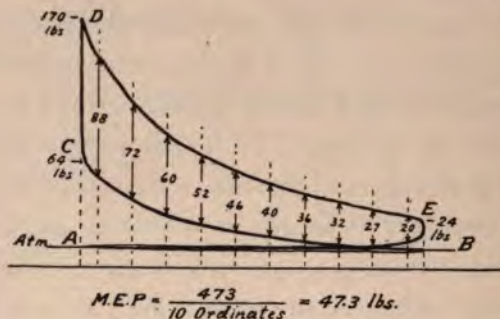


Fig. 60.

H. P. of a gas engine from the indicator diagram even when the recognized rating of the engine is actual H. P., so that the friction and mechanical efficiency of the engine can be computed; and this is performed as follows:

The average or mean pressure of the diagram is obtained either by the use of the planimeter or by drawing vertical lines at suitable intervals as shown in Fig. 60. The length of each of these vertical lines or ordinates is taken; these added together, and divided by their number give the average length and, in accordance with the scale to which the piston spring of the indicator is tested, also show the average or mean effective pressure. This measurement, it should be noted is taken from the line B C. The space between that line and the atmospheric line, A B, representing the pressure

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of compression, is neglected in measuring the indicator diagram, seeing that the work represented in that space of compressing the charge before ignition is returned on the expansion stroke.

The average length then of these lines being determined by a scale corresponding to the strength of the spring, the mean effective pressure, that is, the average pressure existing throughout the stroke is ascertained.

INDICATED HORSE POWER.

Reference has been made to the graphical representation of work performed, when it was shown that the foot-pounds depends upon the distance through which a force moves. Consequently in determining the indicated horse power, the

following formula is used:
$$\text{I. H. P.} = \frac{p l a e}{33,000}$$

where—

p represents the mean effective pressure in the cylinder;

l the length of the stroke in feet;

a the area of the piston in square inches;

e the number of explosions per minute.

For instance, with a gas engine having a mean effective pressure of 50 lbs., the length of stroke 12 inches, an area of the piston of 78 inches, and with 200 explosions per minute (in determining the indicated H. P. it is necessary to count the explosions, not the revolutions per minute) the I. H. P. can be determined by the following calculation:

$$\text{I. H. P.} = \frac{p l a e}{33000} = \frac{50 \times 1 \times 78 \times 200}{33000} = 23.63.$$

MECHANICAL EFFICIENCY.

The indicated H. P. of an engine of course will always be greater than the actual, the difference between the two being

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represented by the power absorbed by the friction of the engine itself; the ratio between B. H. P. and I. H. P. is known as the mechanical efficiency of an engine; thus if the I. H. P. is shown to be 100 and the actual H. P. is shown to be 80, the difference of 20 H. P. being absorbed by friction of the engine itself, the mechanical efficiency of that engine is stated to be 80%.

TWO-CYCLE DIAGRAMS.

With two-cycle engines where the compression is performed in the crank chamber, this must be indicated to determine the



Fig. 61a.

Diagram from Four-Cycle Engine. 256 R. P. M. 75.8 lbs. M. E. P.
Scale 240 lbs.

mean pressure existing in that chamber due to the compression of the air before it enters the cylinder, while the motor

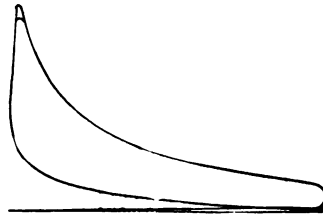


Fig. 61b.

Diagram Four-Cycle Engine. 20" dia. 27" stroke. 182 R. P. M.
72.5 equals M. E. P. Producer Gas.

cylinder, that is, the cylinder in which the expansion takes place, is indicated in the same way as with four-cycle engines.

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In calculating the power developed by a two-cycle engine the mean effective pressure is ascertained by computing the average pressure obtaining in the area BCDE as shown in



Fig. 61c.

Diagram Two-Cycle Gas Engine. $25\frac{1}{2}$ " dia. 43" stroke. 100 R. P. M.
80 lb. M. E. P. Scale equals 200 lbs.

Fig. 60; while the work performed in compressing the charge and determined by the average pressure of the crank



Fig. 61d.

Crank Case Card. 2.43 lbs. M. E. P. Scale 10 lbs.

chamber diagram, must be deducted from the total of the power developed in the motor cylinder.

With the two-cycle engine having auxiliary air pump or air and gas pump, in a similar way the power shown by the indicator diagrams taken from the air and gas pumps must be deducted from the total power computed from the diagram taken from the motor cylinder.

VARIOUS DIAGRAMS.

Figs. 61, 62, show various cards taken from different two and four-cycle engines, the characteristics of those cards being noted beneath them. As stated, the chief purpose of indicat-

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ing an internal combustion engine is to detect errors of design or adjustment; to ascertain if the proper performance



Fig. 61e.

Two-Cycle Gas Pump Card. 5.4 lbs. M. E. P. Scale equals 20 lbs.

is obtaining in the cylinder; and in order to illustrate defects which may exist the following distorted diagrams are shown.

DEFECTS SHOWN BY DIAGRAMS.

In Fig. 63 an indicator card is shown from an engine where the ignition is too late. This may be caused by too

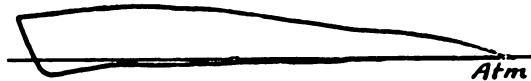


Fig. 61f.

Air Pump Card. 5.2 lbs. M. E. P. Scale equals 20 lbs.

late timing of the electric spark or other igniter (the timing of the spark depending upon the richness of the explosive

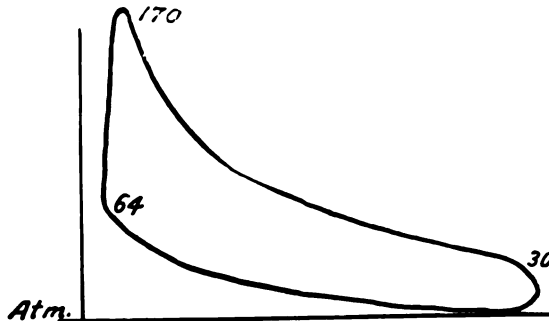


Fig. 61g.

Diagram of Four-Cycle Oil Engine. 7" dia. 12" stroke, 260 R. P. M. 51 lbs. M. E. P. Scale 80 lbs.

mixture and also on the speed of the engine). Further, such defect may be caused by insufficient compression of the

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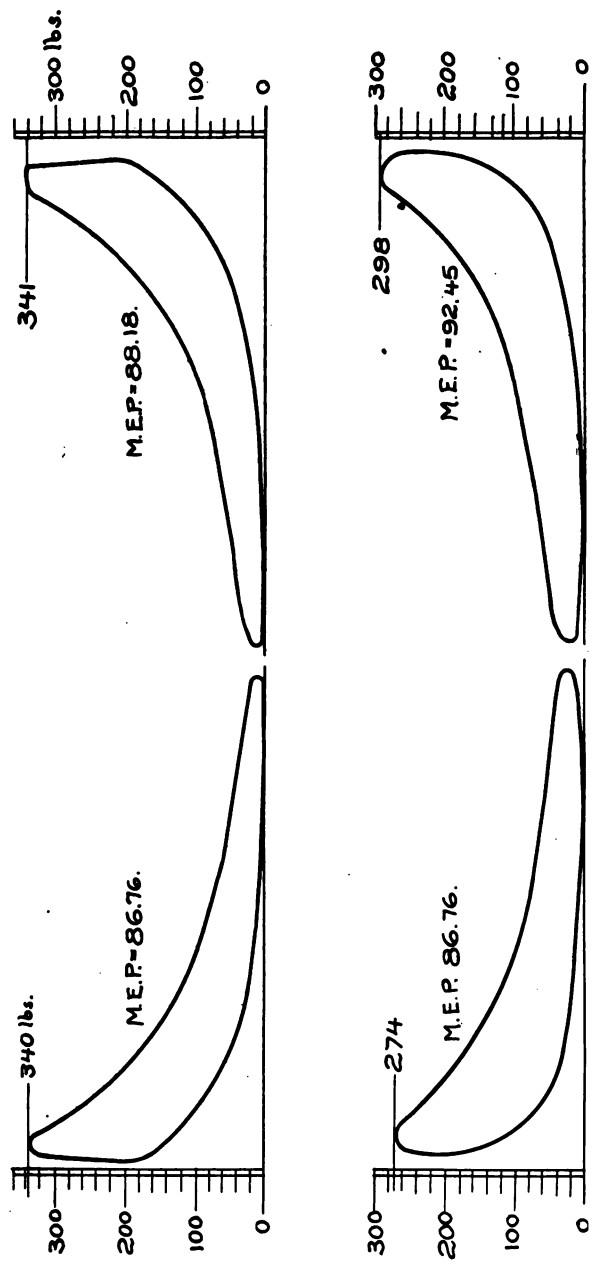


Fig. 62.
Diagrams from Four-Cycle Double Acting Gas Engine.

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gases before ignition. This remark particularly applies to engines where the ignition is automatic, that is, where no electric or tube igniter is used and where the ignition of the gases depends on the heat caused by compression of the gases

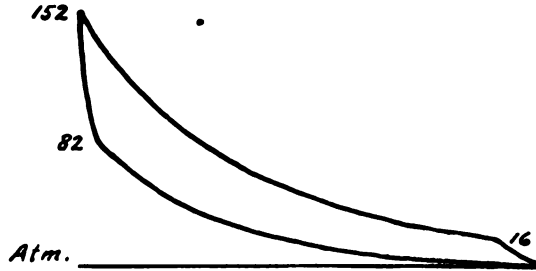


Fig. 61h.

Diagram Two-Cycle Oil Engine. 10" dia. 12" stroke. 300 R. P. M.
29.5 equals M. E. P. Spring equals 120 lbs.

before ignition, together with the heat of the automatic igniter, such as, for instance in various kerosene oil engines.

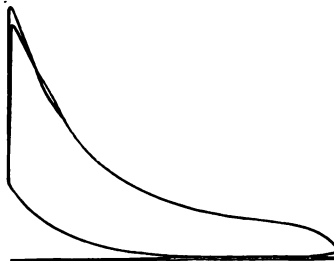


Fig. 61i.

Diagrams from Four-Cycle Engine. 10" dia. 18" stroke. 170 R. P. M.
M. E. P. 89.6 lbs.

Fig. 64 shows a card where the ignition is too early; that is, the ignition occurs before the piston reaches the back end of the cylinder. This entails loss of power as the pressure due to ignition in the cylinder causes back pressure on the piston, and as the mean effective pressure is reduced when this

TESTING.

occurs, the power developed will be likewise reduced when pre-ignition takes place.

Fig. 65 shows throttling of the exhaust. This may be due

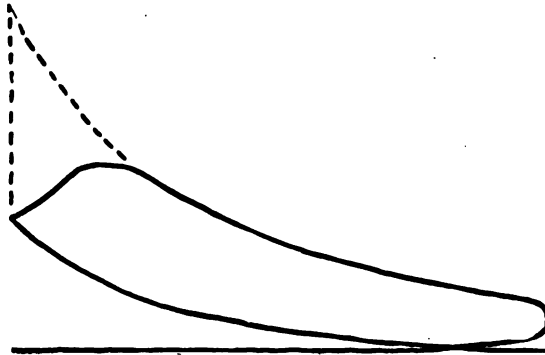


Fig. 63.

to improperly designed ports in the cylinder, valves or valve chamber, the valves and passages being too small to allow proper discharge of the gases without creating back pressure as shown at Fig. 65; or the defect may be caused by too late

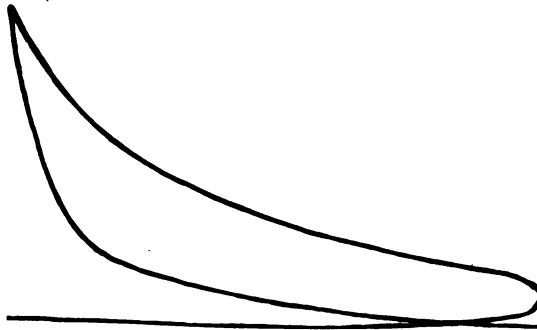


Fig. 64.

opening of the exhaust valve, or again by excessive friction of the gases in the exhaust pipe due to too small pipe or one with numerous sharp bends in it.

GAS ENGINE PRINCIPLE AND PRACTICE.

Fig. 66 shows a throttled suction. It will be noted here that a slight vacuum is formed in the cylinder towards the end of the suction stroke, which plainly indicates that the

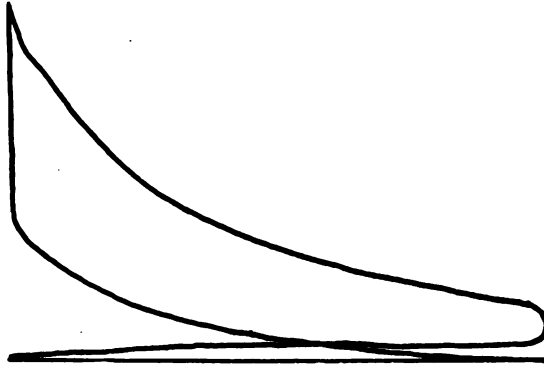


Fig. 65.

air valve is not large enough to allow the air to enter freely into the cylinder or that the passages leading to the valves are too small. Again improper opening of the air valve due

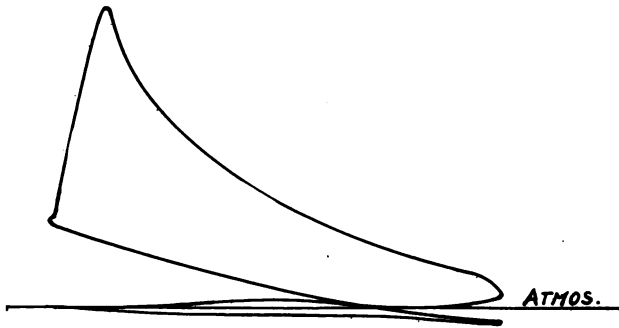


Fig. 66.

either to improper setting of the valve motion or to a too heavy spring where the valve is automatic (that is, where the valve is opened by the suction of the air on the movement of

TESTING.

the piston and closed by a light spring) may cause an improper result as shown in this diagram, Fig. 66.

LIGHT SPRING DIAGRAM.

The operation of the air and exhaust valve and the conditions existing during the air inlet and exhaust periods are best shown with a light spring indicator card. That is, the normal size spring of, say, 200 lbs. is taken out of the indi-

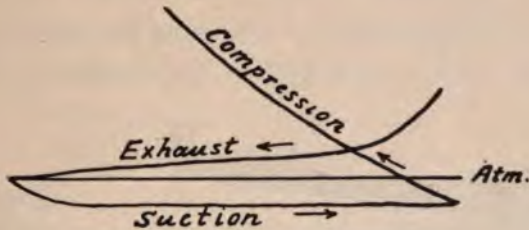


Fig. 67.

cator, a stop is placed on the piston rod of the indicator and a light spring equivalent to, say 10 or 20 lbs. to the square inch is put in its place. In this way a diagram showing only



Fig. 68.

the pressures up to say about 30 lbs. in the cylinder are shown in the diagram and therefore a greater space on the card is given to the low pressures of exhaust and air inlet, from which view it is easier to detect improper conditions than it is

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on the ordinary diagram. Fig. 67 shows a diagram of this description.

FRICTION CARD.

What is known as a friction card is shown at Fig 68. This diagram is taken with the engine working without load; the slight pressure shown on it is that required to overcome merely the friction of the engine itself.

PLANIMETER.

The Crosby planimeter or averaging instrument is shown at Fig. 69. No. 1 planimeter is the simplest form of the

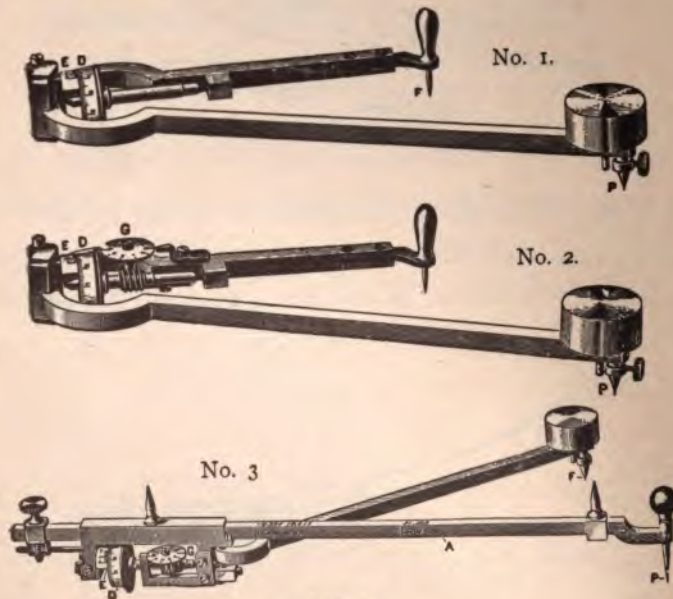


Fig. 69.

instrument, having but one wheel, and is designed to measure areas in square inches and decimals of a square inch. The figures on the roller wheel, D, represent units, the gradu-

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ations tenths, and the vernier, E, gives the hundredths. F is the tracer and P is the pivot.

Fig. 69 represents the No. 2 planimeter, which is the same as the No. 1, with the addition of a counting disc, G, the figures on which represent tens and mark complete revolutions of the roller-wheel. By this means areas greater than 10 square inches can be measured with facility. The result is given in square inches and decimals, and the reading from the roller wheel and vernier is the same as with No. 1.

Fig. 69 represents the No. 3 planimeter, which differs somewhat in design from the two previously described. It is capable of measuring larger areas, and by means of the adjustable arm, A, giving the results in various denominations of value, such as square decimeters, square feet and square inches; also of giving the average height of an indicator diagram in fortieths of an inch, which makes it a very useful instrument in connection with indicator work.

DIRECTIONS FOR MEASURING AN INDICATOR DIAGRAM WITH A NO. 1 OR NO. 2 PLANIMETER.

Care should be taken to have a flat, even, unglazed surface for the roller-wheel to travel upon. A sheet of dull-finished cardboard serves the purpose very well. Set the weight in position on the pivot end of the bar, P, and after placing the instrument and the diagram in about the position shown in Fig. 70, press down the needle point so that it will hold its place, set the tracer; then at any given point in the outline of the diagram, as at F, adjust the roller-wheel to zero. Now follow the outline of the diagram carefully with the tracer point, moving it in the direction indicated by the arrow, or that of the hands of a watch, until it

GAS ENGINE PRINCIPLE AND PRACTICE.

returns to the point of beginning. The result may then be read as follows: Suppose we find that the largest figure on the roller wheel, D, that has passed by zero on the vernier, E, to be 2 (units) and the number of graduations that have also passed zero on the vernier to be 4 (tenths), and the number of graduation on the vernier which exactly coincides with the graduation on the wheel to be 8 (hundredths), then we have 2.48 square inches as the area of the diagram. Di-

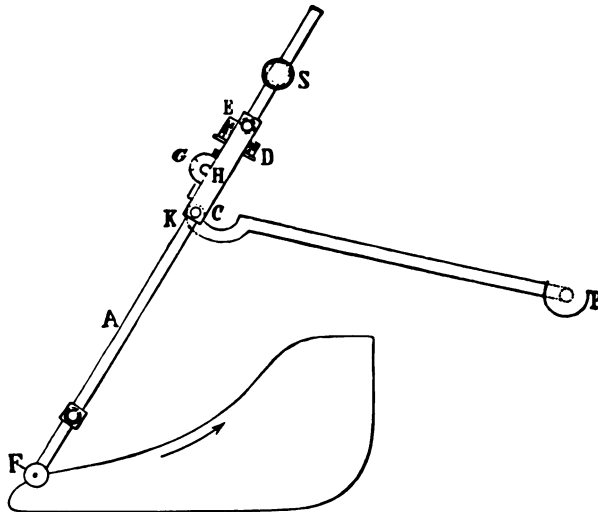


Fig. 70.

vide this by the length of the diagram, which we will call three inches, and we have 0.8266 inch as the average height of the diagram. Multiply this by the scale of the spring used in taking the diagram, which in this case is 40, and we have 33.06 lbs. as the mean effective pressure per square inch on the piston of the engine.

DIRECTIONS FOR USING THE NO. 3 PLANIMETER.

No. 3 planimeter is somewhat differently manipulated, although the same general principle obtains. The figures on

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the wheels may represent different quantities and values, according to the particular adjustment of the sliding arm A. If it is desired merely to find the area in square inches of an indicator diagram, set the sliding arm so that the 10-square-inch mark will exactly coincide with the vertical mark on the inner end of the sleeve H at K. The sliding arm is released or made fast by means of the set-screw S.

With the wheels at zero and the planimeter and diagram in the proper position, trace the outline carefully and read the result from the roller wheel and vernier, the same as directed for the No. 1 and No. 2 instruments.

CONTINUOUS DIAGRAMS.

The "Mathot" indicator diagram which shows the pressure of consecutive explosions in the gas engine cylinder is of great value where it is desired to compute the average pressure of a number of impulses. This instrument (not illustrated here) is much used especially in testing the large size engines.

CHAPTER VI.

THE USE OF CRUDE OILS, FUEL OILS, DISTILLATE AND ILLUMINATING OILS, VAPORIZERS, ETC.

The more general use of crude oils and fuel oils in internal combustion engines has found favor with power users mostly on account of the great economy effected by their use. This statement is particularly true in localities where crude oil, more suitable for fuel than for refining purposes, has in recent years been found in large quantity, notably California, Texas and Kansas, while in all parts of this country as well as possibly in others the supply of fuel oil (sometimes known as gas oil) has become more plentiful by reason of increased use of gasoline and illuminating oil.

As the amount of crude oil distilled is increased, the output of light oils, illuminating oils and fuel oils is also increased.

Fuel oil has for a number of years been used for fuel under boilers instead of coal, and for this purpose it was found advantageous, as the weight of liquid fuel used is very much less than the weight of coal required for the same amount of evaporation. About 160 gallons of fuel, under the boiler, is equivalent to one ton of coal.

In Europe in locomotives it is stated that 55% in weight of fuel is saved by using petroleum refuse instead of anthracite coal.

The use of oil fuel in internal combustion engines shows further economy as compared with its use under the boiler;

THE USE OF CRUDE OILS, FUEL OILS, DISTILLATES, ETC.

the cost of installation is decreased; the cost of maintenance is less, less attention is required and less fuel is consumed per horse power furnished.

COMPARISON OF COST OF POWER.

As an instance of the comparative cost of producing power in the Southern states it may be stated that with Texas oil at 80 cents per barrel, or approximately two cents per gallon, an actual H. P. per hour can be produced for one-fourth cent (assuming that the engine consumes one pint per H. P. hour, and there are many engines doing much better than this). With steam the cost per actual H. P. per hour using Alabama coal at \$3 per ton, would not be less than three-fourths cent per actual H. P. per hour. This comparison neglects other economies, but taking the fuel alone these two methods of producing power, show by comparison, a very large economy in favor of the oil engine.

CRUDE OILS.

Crude oil is a mineral product obtained from the earth at various depths from subterranean wells and is either pumped from the earth or issues under pressure. The chief supplies are taken from the shores of the Caspian Sea, the region of the Caucasus Mountains in Russia; at Baku, Batoum, and in the United States in the Central Eastern states, Pennsylvania, New York, Ohio and West Virginia; in the region of Beaumont and Corsicana in Texas; in California around Kern County, Coalinga and Los Angeles. Large supplies of crude oil are also found in Kansas and other Southwestern states, while reference has recently been made to the possibilities of large supplies being secured from the Northwest Territory of Canada.

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Crude oils can be roughly divided into two sections; that having an asphaltum base and that having a paraffine base. To the latter belong mostly those of Russia and the Allegheny or Pennsylvania product; a very slight quantity of this is also found in California and Texas.

Nearly all Texas crude oil, however, as well as that of California has an asphaltum base.

In Scotland, what is known as shale oil is procured by distillation of bituminous matter.

DISTILLATION.

The process of distillation briefly described is performed by gradually heating in a retort, when what is known as "fractional" distillation occurs.

Vapors having high inflammability (those having a low flash point) such as naphtha, gasoline, and benzine are first given off in this process. As the temperature of the retort is increased, heavier gases are liberated which when condensed are known as illuminating oils, such as ordinary kerosene (WW 150° F. flash point) then is produced what is known as gas or fuel oil followed by lubricating oils and then remains a heavy liquid sometimes used for fuel, and then a solid deposit.

The fuels which chiefly concern this subject are the crude oils, the illuminating oils, the fuel or "gas" oils, and distillates.

The average specific gravity of the American product found in Pennsylvania or the Allegheny region is 0.79,* while that of the Russian product is 0.85. The Texas crude oil, many samples of which have come under the notice of

*Specific gravity of 0.79 means that a gallon weighs 79/100 as much as a gallon of water.

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the writer, have a specific gravity varying from 0.86 to 0.92 or even heavier. Some of the California crude oils are as heavy as 11.5° Baume.[†]

Distillate is a comprehensive term. There are various grades on the market. Those known as "common," "first run," and "slop" distillate are simply the crude petroleum with the asphaltum taken out, consisting of all the original constituents of the oil except the asphaltum. The gravity of these ranges from 22° to 28° Baume, and varies as does that of the crude petroleum, from which it is produced.

Re-distillation of this distillate will furnish products ranging in gravity from 15° to 80° Baume and even possibly those of higher or lower gravity. All these products are known as "distillate," being distinguished from each other by naming the gravity of each.

Again, by a clarifying process the higher gravity distillates above referred to, are made into gasoline, kerosene, and "engine distillate." The medium gravity is made into "stove distillate" and the lower gravity into lubricating oil. Such constituents of the original "common" distillate not capable of being clarified are used as fuel. The process of distillation is as follows: The crude oil is heated in a closed still (arranged to allow the vapors to issue from

[†]Liquids are generally tested by an instrument called a Baume hydrometer. It is a closed glass tube having a bulb filled with shot at one end. On the tube are marked a series of divisions arbitrarily called degrees. The loading of shot at one end of the tube causes the instrument to float in the upright position and it of course sinks to a greater or less depth in a liquid according as the liquid is light or heavy. That is, it sinks deeper in a light liquid such as gasoline than it does in water. There are two different scales on even the Baume hydrometer—one scale for liquids heavier than water, and one for liquids lighter than water. On the scale for liquids the reading when the instrument is placed in water is zero, but when the instrument is graduated for liquids lighter than water—the scale for water reads 10°. This shows only one of the confusions which arise from the use of arbitrary scales—the Baume hydrometer with its two scales is not the only one in use—there are a number of others in use—as for instance, that by which Standard Oil products 68°, 72°, 76° and 88° gasoline is graded; as these degree ratings bear no relationship to the Baume readings. The Baume and in fact all arbitrary scales on the hydrometer are going out of use. It is possible to buy instruments on which the scale represents a direct measure of the weight of the liquid compared with an equal volume of water. In the reading above of 11.5° Baume the density of the oil is about 99/100—as heavy as water. And on the new style of hydrometer the reading would be 99—that is, when the instrument was put in an oil of this density it would sink down one per cent. further than it would in water.

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the upper part, the heavier or solid matter being drawn off from below) to 400-500° F. The most volatile part of the oil is then first vaporized. As the temperature is gradually raised to 800° F., the less volatile parts are vaporized. Condensation of the vapor is effected by passing it through a coil of pipe immersed in cold water. The distillates of different gravity can be separated in the process of distillation as the lighter products will come off first, followed by the heavier grades. If a more thorough separation of the constituents is required, this is effected by repeating the process of distillation, each product being separately distilled.

The distillate used in the ordinary gasoline engine should be of 45° to 50° Beaume gravity with a low flash point, about the same as gasoline. This fuel can be used in all engines designed to use ordinary gasoline without change. Sometimes gasoline is used to start the engine instead of distillate and then when the engine has become heated, distillate is used with equal satisfaction as gasoline.

The distillate somewhat heavier, that is, about 34° Beaume, is used chiefly for domestic purposes (heating and cooking). The heavier distillates, that is, those having 24° Beaume, can be used with perfect satisfaction in the different oil engines in which the vaporizer is heated by external lamp or other means of vaporization is furnished as stated.

The following table (II) shows the ultimate composition of Pennsylvania, Beaumont and Ohio oils, while table (III) shows the calorific value of various descriptions of petroleum or crude oil.

In order to obtain the proper combustion of fuels under discussion in the internal combustion engine, it is necessary

THE USE OF CRUDE OILS, FUEL OILS, DISTILLATES, ETC.

that they be heated above their boiling points (which, however, vary, being approximately 300° F.) properly mixed with the correct proportion of oxygen, and ignited.

COMBUSTION.

TABLE II—ULTIMATE COMPOSITION OF FUELS.*

	Beaumont. Texas.	Pa.†	O.‡
Carbon	80.03	86.10	85.00
Hydrogen	12.30	13.90	13.80
Sulphur	1.75	0.06	0.60
Oxygen and Hydrogen	0.92	—	0.66
Loss on treatment with excess of H ₂ SO ₄ (sulphuric acid)	39.00	—	30.00

†Engler. ‡Mabery, Noble Co.

TABLE III—HEATING VALUE OF FUELS.
(B. Redwood.)

Description of Fuel.	Locality.	Sp. Grav.	Chemical Compo.			Heat Value.
			Carbon.	Hydrogen.	Oxygen.	B. T. Us. per lb.
Heavy Crude.....	Pa.	0.886	84.9	13.7	1.04	19.209
Light Crude.....	Pa.	0.816	82.0	14.8	2.3	17.935
Heavy Crude.....	W. Va.	0.873	83.5	13.3	3.2	18.324
Heavy Crude.....	Baku	0.938	86.6	12.3	1.1	19.440
Light Crude.....	Baku	0.844	86.3	13.6	0.1	20.628
Heavy Crude.....	Ohio	0.887	84.2	13.1	2.7	18.718
Heavy Crude.....	Texas	0.921	85.0	12.3	0.9	18.500

*Journal of the Society of Chemical Industry, Vol. 20, No. 7.

These processes are performed in various ways as will be hereafter described; theoretically the correct amount of air required to furnish sufficient oxygen for the complete combustion of one pound of petroleum, is about 190 cubic feet (when measured at 60° F. and at atmospheric pressure).

As the characteristics of the different petroleums vary, this theoretical amount of air of course must vary some also. The chemical analysis showing the constituent parts of the fuel renders it possible and easy to calculate exactly the amount of air required.

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On examination of various types of engines it will be found that a very much larger amount of air is usually supplied than that above stated, and this is the case so that a complete combustion may be brought about in the engine cylinder, seeing that burnt products from previous combustion and other neutrals are in the cylinder before the pure air enters.

VARIOUS CRUDE OIL VAPORIZERS.

The use of crude oil and the heavier fuel oils in internal combustion engines, may be classified as follows:

a.—The separate or external vaporizer, consisting of an apparatus in which the crude oil is introduced in a liquid state as it comes from the earth and where it is heated by the exhaust gases of the engine, the gaseous vapor liberated by this heat being drawn into the ordinary gas engine and means being arranged in the vaporizer or retort to extract the deposit of solid matter or carbon.

b.—The internal vaporizer, that is, the vaporizer being a constituent part of the engine. The best known instance of which is the Hornsby-Akroyd oil engine.

c.—Vaporization in the cylinder of the engine itself, being subjected to very high compression and temperature in the cylinder. The best known example of which is the Diesel engine.

d.—The manufacture of oil gas in a separate apparatus. In this case the gas becomes fixed and does not readily condense again and is manufactured more generally for illuminating purposes from the gas oil previously referred to or similar products. The first oil gas producer was the subject of an English patent at the beginning of the last century. One of the simplest manufactured devices of this description

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is the Mansfield oil gas apparatus, which consists of a strong cast iron chamber lined with fire clay. This chamber is heated to nearly $2,000^{\circ}$ F. and has an inner cast iron retort to which the oil to be vaporized flows through a pipe having a syphon bend in it to avoid leakage of gas. The oil gas or vapor rises in the retort and passes over the upper part of the retort to a vessel containing water where the heavy products are separated from the gas, whence the gas passes to a gas holder.

EXTERNAL TYPE OF VAPORIZER.

There are now many external vaporizers in general use. Illustration of this type is shown at Figs. 71, 72. It is made

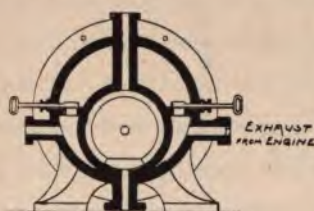


Fig. 71.

on the Pacific Coast and consists of a cast iron chamber with means for proper connections so that the exhaust gases from

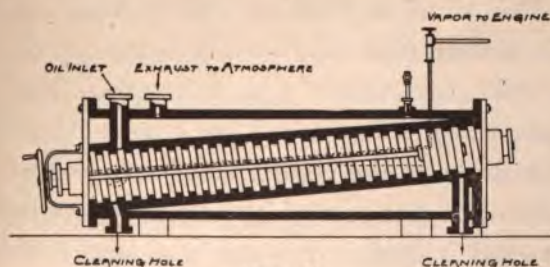


Fig. 72.

the engine can pass through it, thus furnishing the necessary heat required for vaporization of the crude oil. In this

GAS ENGINE PRINCIPLE AND PRACTICE.

chamber, as will be seen from the illustration, is an inner casing to which the crude oil is fed. Immediately the fuel enters this heated chamber it is vaporized and the vapor rises in it. This chamber is in direct communication through suitable valve with the engine cylinder and on the suction stroke of the engine (that is, the period preceding compression) the gas is drawn into the cylinder and there mixed with the proper amount of air. It will be noted in this case a revolving cleaner is supplied which is utilized to loosen the deposit of carbon or asphaltum formed when using crude oils of an asphaltum base. This deposit of carbon is periodically removed from the vaporizer by the openings at the lower side.

The Acme retort may be mentioned as another of the various apparatus made for vaporizing or gasifying the crude and heavier oils or distillates. It is used extensively in the far west and Pacific Coast in connection with stationary engines as well as for engines for marine purposes. It consists of a cast iron casing having three compartments. The exhaust gases from the engine are made use of to maintain the proper temperature necessary for vaporizing crude oil. The fuel is deposited onto a wheel which revolves inside this casing. This wheel is provided with pockets and revolves around the exhaust pipe. As the oil is heated on coming into proximity with the exhaust pipe it is transformed into an unfixed gas which is drawn into the engine cylinder during the suction stroke in the regular way. As part of the fuel only is vaporized that part which remains is carried over by this wheel and is deposited in the base of the retort from which it can be easily withdrawn. With this apparatus in connection with large engines it is frequently found advantageous to inject a small spray of water into the gases as they

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pass to the engine. By this means the temperature of the gas is reduced and with high compression pre-ignition is avoided.

It is claimed that with this apparatus one brake horse power can be developed with the consumption of a pint of crude oil per hour.

Another retort is that patented by Lucke and VerPlanck. This is shown at Fig. 74.

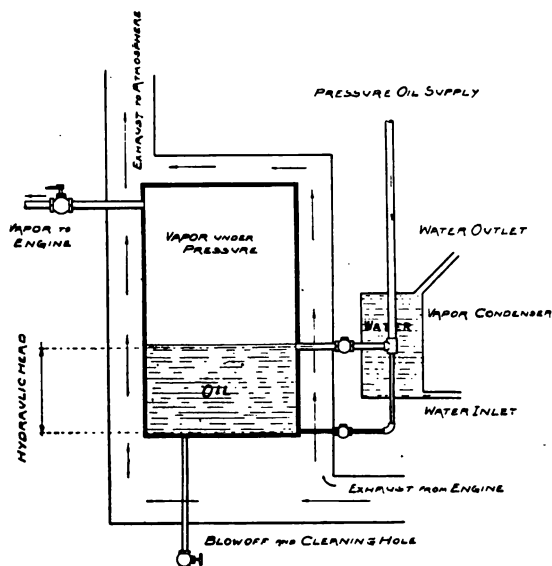


FIG. 74.

As will be seen from the illustration it consists of a chamber containing the fuel which is provided with oil supply and vapor discharge. A blowoff valve being provided emitting the solids or other matter which may be contained in the fuel and which cannot be vaporized, when using crude or inferior fuel. The vapor supply pipe has a valve controlled by the engine governor. The fuel chamber is heated by the exhaust gases which pass around in the outer chamber, which is, of course, suitably connected to the exhaust pipe of the engine.

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Carbonization in the chamber is prevented by the fuel always being kept at a temperature above the boiling point of the oil. It also provides a small amount of oil always at the boiling point and ready to give off vapor, directly the pressure in it falls; thus if five lbs. pressure is maintained in the chamber the temperature of the oil corresponds to this pressure. Should the load on the engine require a heavy supply of oil vapor the pressure may fall to three lbs. and then the super-heated liquid freely gives up vapor in the same way as the

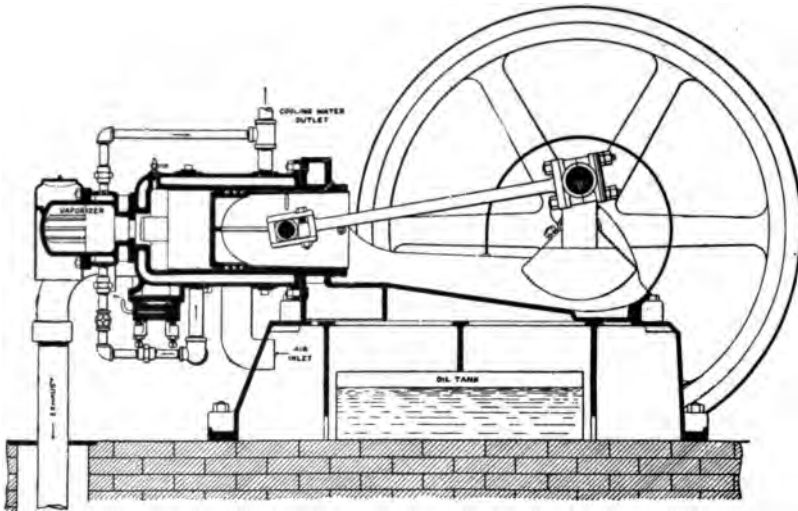


Fig. 75.

steam boiler would furnish steam without additional heat. Pressure in the chamber is kept constant by the elevation of the oil tank or by compressed air on the surface of the oil in a closed tank. Fuel enters the bottom of the oil chamber and vapor is constantly being blown off through a check valve placed above as will be noted in the illustration; there are two check valves at different heights making the pressure on the upper one less than the pressure on the lower one, the

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difference in pressure being due to the hydraulic head. These two check valves connect with the condenser and then when the requirements of the engine do not take all the vapor supplied in the vaporizer, part of it is condensed and returns to the vaporizer in a liquid state.

INTERNAL TYPE OF VAPORIZER.

The internal vaporizer next mentioned at "b" is made in this country and in Europe; the best known example is the "Hornsby-Akroyd" oil engine. The vaporizer and cylinder of this engine are shown in section at Figs. 75 and 76. In this type the oil is introduced into the vaporizer placed at the back of the cylinder in liquid form. The air is introduced

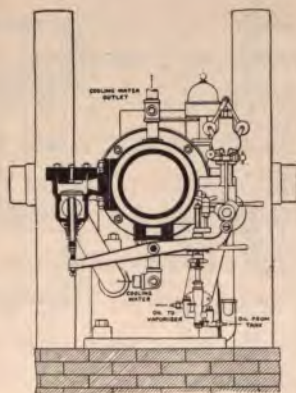


Fig. 76.

into the cylinder during the suction period of the cycle (this is a four-cycle engine), thus the cylinder simultaneously becomes filled with air and the vaporizer with a spray of oil or oil vapor. During the compression the air in the cylinder being forced into the vaporizer becomes properly mixed with it, and an explosive mixture is formed. The heat necessary for vaporization is first supplied by exter-

nal lamps and when in operation by the continued combustion of the fuel in the vaporizer. Ignition being also caused by the heated walls of the chamber.

The deposit of carbon frequently found where crude oil is used does not enter the cylinder or come in contact with the piston or piston rings, but is formed in the vaporizer cap. A flange cover at the back of the cap (not shown in this illustration) allows the quick removal of this deposit periodically, usually about every 60 hours.

Figs. 77, 78 show a vertical three-cylinder type oil engine which has recently been designed by the English makers, R. Hornsby and Sons, Grantham, England. It is made in various sizes up to 250 H. P., the larger sizes being of four-cylinder. The engine illustrated is of 80 H. P. This engine is designed more especially for operating generators direct connected and therefore runs at a comparatively high speed. It is also used for marine work. It is very compact, that shown (80 H. P.) being 8 feet x 5 feet 9 inches x 6 feet 6 inches and weighs approximately 14,000 lbs. and operates at 400 R. P. M. The cylinders are 12" diameter by 12" stroke.

The horizontal type of Hornsby-Akroyd oil engine is of somewhat different design to this later type of engine. In this engine the air and exhaust valves are placed in housings in the top cover the vaporizer being placed on the side of the cylinder and horizontally. With this arrangement of the valves the clearance in the cylinder is reduced and consequently higher compression is obtained than in the horizontal type. The accompanying indicator cards, Fig. 79, show the results obtained when using Texas crude oil, Scotch gas oil and refined Russian petroleum the compression pressure varying from 84 to 140 lbs. while the mean effective with refined Russian oil is 56 lbs.

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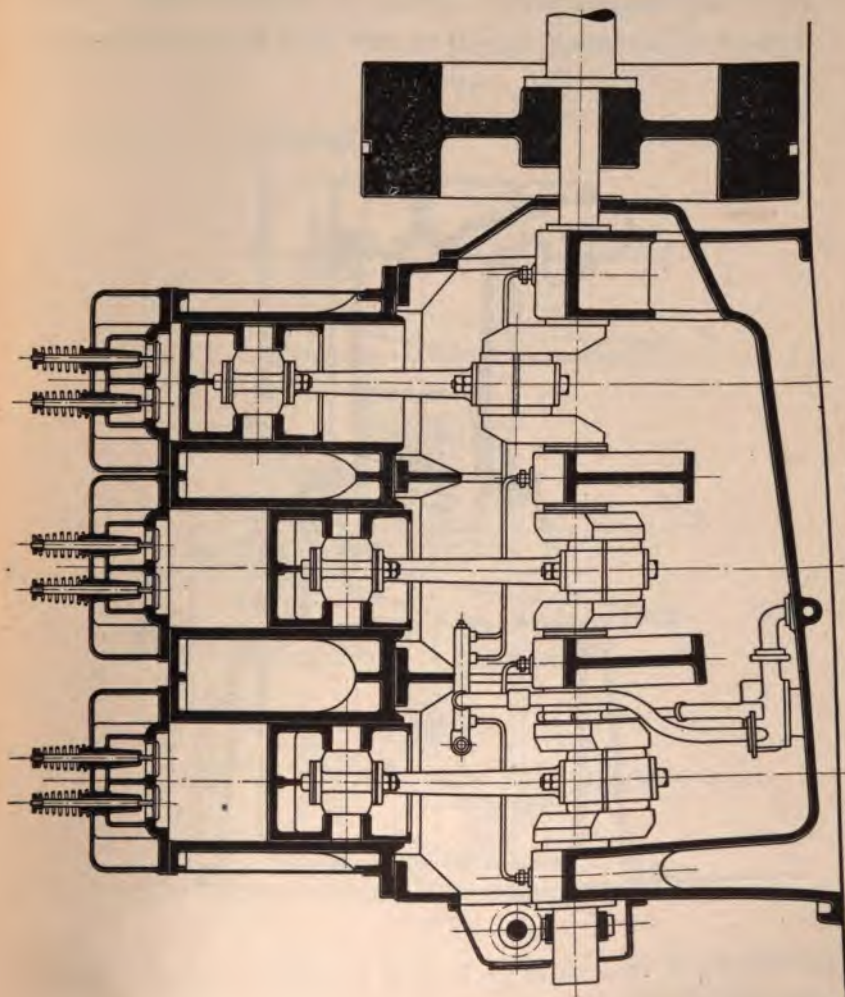


Fig. 77.

GAS ENGINE PRINCIPLE AND PRACTICE.

The ignition of the gases in the cylinder is caused automatically by the heat of compression together with the heat stored in the walls of the vaporizer which chamber is heated for a few minutes before starting by external lamp. The method of governing, as will be seen from the accompanying

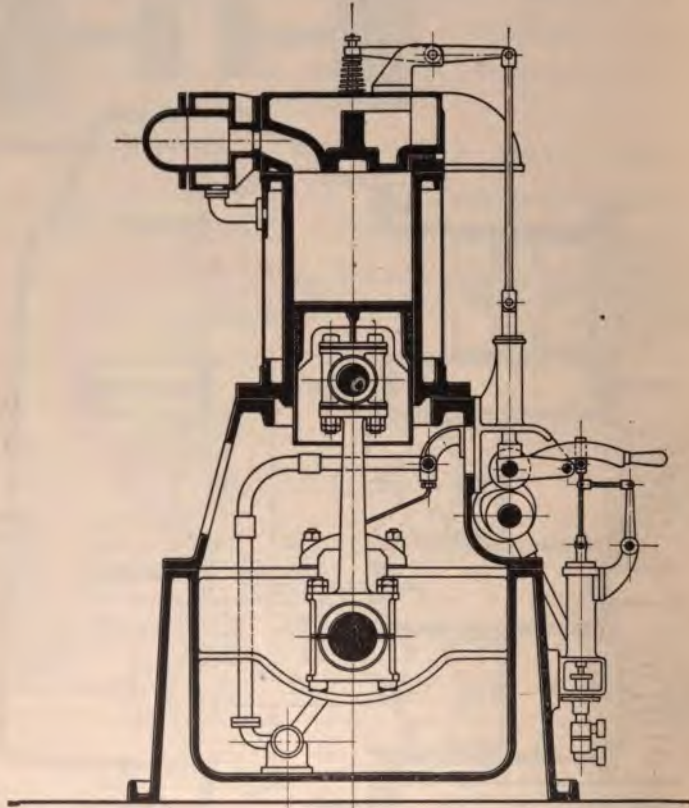


Fig. 78.

illustration, Fig. 78 is performed by lengthening and shortening the stroke of the oil supply pumps. By this means very close regulation is obtained; the following is a test made at the makers' works in England.*

*"Engineering" (London) March 31, 1905.

THE USE OF CRUDE OILS, FUEL OILS, DISTILLATES, ETC.

Scale - $\frac{1}{300}$.

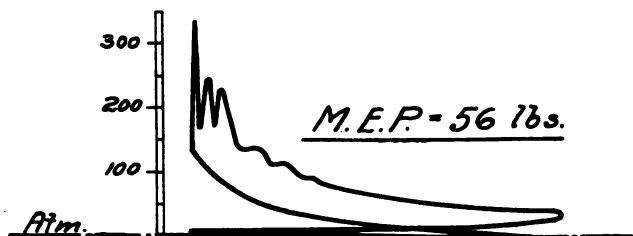
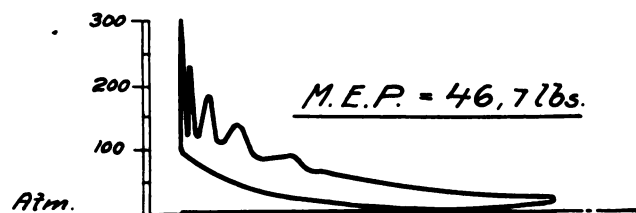
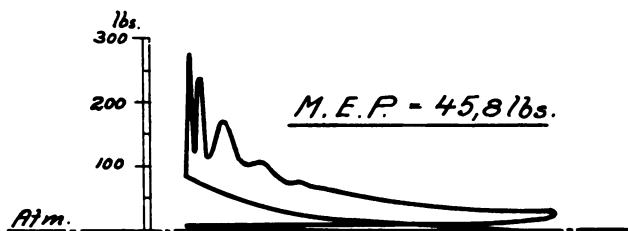


Fig. 79.

GAS ENGINE PRINCIPLE AND PRACTICE.

TABLE IV.

*Summary of 12 Hours' Trial on 80 Brake Horse Power
Three-Cylinder Vertical Oil Engine on Brake
Using Scotch Gas Oil.*

Mean speed of engine.....	396.5 R. P. M.
Mean brake horse power.....	76.8
Mean consumption, lbs. of oil used per hour.....	60.7
Mean consumption, lbs. of oil used per brake horse horse power per hour.....	0.790
Mean circulating water used in lbs., per hour.....	15,720
Mean temperature of circulating water—inlet....	62.1° F.
Mean temperature of circulating water—outlet....	97.1° F.
Mean temperature of exhaust gases.....	747° F.
Mean temperature shop	67° F.
Calorific value of oil per lb.....	19,000 B. T. U.'s.
Thermal efficiency of engine on brake H. P.....	17.5%
Loss in water jacket.....	45 %
Loss in exhaust gases and radiation.....	37.5%
	100.00

TABLE V.

*Summary of a Trial on above Three-Cylinder Vertical Oil
Engine with Compound Wound Dynamo,
Using Refined Russian Oil.*

Mean speed of engine, ...	394 R. P. M.
Electrical load.....	67.6 Kw. 90.584 E. H. P.
Brake load based on dynamo efficiency of 90%...	100.6
Consumption of oil per kilowatt hour.....	0.97 lb.
Consumption of oil per electrical H. P. hour....	0.723 lb.
Consumption per brake horse power hour.....	0.65 lb.

THE USE OF CRUDE OILS, FUEL OILS, DISTILLATES, ETC.

TABLE VI.

*Summary of Six Hours' Trial on 80 Brake Horse Power
Three Cylinder Vertical Oil Engine, with Com-
pound Wound Dynamo, Using Texas Oil.*

Mean speed of engine	393.8 r. p. m.
Electrical load, 84 volts, 602 amperes, 50.568 kw., 67.76 E. H. P.	
Brake load based on dynamo efficiency of 90 per cent.,	75.29
Mean consumption—pounds of oil used per hour....	58.03
Mean consumption—pounds of oil used per kilo- watt hour, ...	1.15
Mean consumption—pounds of oil used per elec- trical horse power per hour, ...	0.85
Mean pounds of oil used per brake horse power per hour	0.77
Mean temperature of circulating water—inlet.....	53.7° F.
Mean temperature of circulating water—outlet.....	94.9° F.
Mean temperature of exhaust gases.....	727.3° F.
Mean circulating water used in pounds per hour....	12,000
Mean temperature of shop	57° F.

THE DIESEL ENGINE.

The well-known Diesel engine is the best example of the type referred to at "c." In this engine, which is of the four-cycle type, shown in section at Fig. 80, the liquid fuel is introduced into the cylinder after compression is completed. The pressure of compression is carried very much higher than in other types of internal combustion engines, the heat generated by compression being sufficient to cause combustion of the fuel. The injection of oil is made through a valve placed

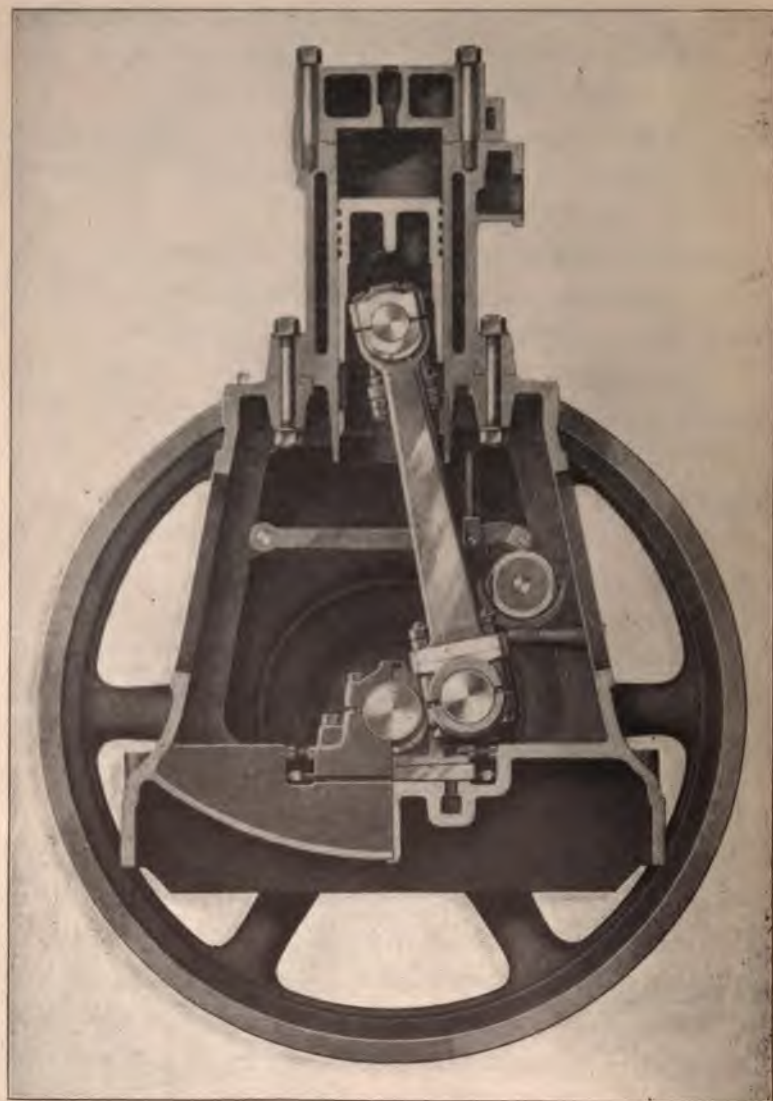


Fig. 80.

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at the top of the cylinder as shown in Fig. 81. As the fuel enters the cylinder after the period of compression (about 600 lbs. per square inch) is necessary to inject the fuel. For this purpose an independent air compressor is used, the air necessary to support combustion being introduced through the inlet air valve shown in the illustration.

TABLE VII—TEST OF A 225 H. P. DIESEL OIL ENGINE.

	¼ load	½ load	¾ load	Full Load	Over Load
Length of run in hours.....	1	2	2	4	0.75
Revolutions per minute.....	179.1	177.1	174.5	169.1	161.2
Brake horsepower.....	68.15	133.7	194.9	249.7	263.8
Lbs. of jacket water per B. H. P.-hour.....	29.5	18.9	17.1	15.6	20.1
Average temperature inlet water.....	34	34	34	38.8	40
Average temperature outlet water.....	126.6	135.5	137.9	180	170
B. T. U. per B. H. P.-hour.....	15,103	9,594	9,127	9,029	10,041
Thermal efficiency of engine-2.545 B. T. U. per B. H. P.....	16.8	26.4	27.8	28.1	25.3
Percentage B. T. U. in water jacket.....	18.2	20	19.5	24.3	26
Percentage B. T. U. in exhaust radiation and engine friction.....	65	53.4	52.7	47.6	48.7
Percentage B. T. U. in B. H. P.....	16.8	26.4	27.8	28.1	25.3
Gallons oil per 100 B. H. P.-hours.....	10.6	6.7	6.4	6.3	7
Fuel cost of 100 B.H.P.-hrs. in c with oil at 3.64 c per gal....	38.6	24.5	23.3	23	25.6

VAPORIZERS FOR ILLUMINATING OR LIGHTER OILS.

The vaporizer required for the use of illuminating oil and high grade fuel oils is necessarily less simple in construction than the carbureter for gasoline. There are various types of this apparatus on the market and they have been classified as follows:

1.—The vaporizer into which the charge of oil is injected by a spraying nozzle, being connected to cylinder through a valve and heated by the exhaust gases. Ignition being caused by electric igniter.

2.—That into which the oil is injected with some air, the larger volume of air, however, entering the cylinder through a separate valve and heated by external lamp.

3.—The vaporizer into which the fuel and all the air supply is injected but being without spraying device and heated by external lamp.

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4.—That into which the oil is injected directly, the air being drawn into the cylinder by means of a separate valve,

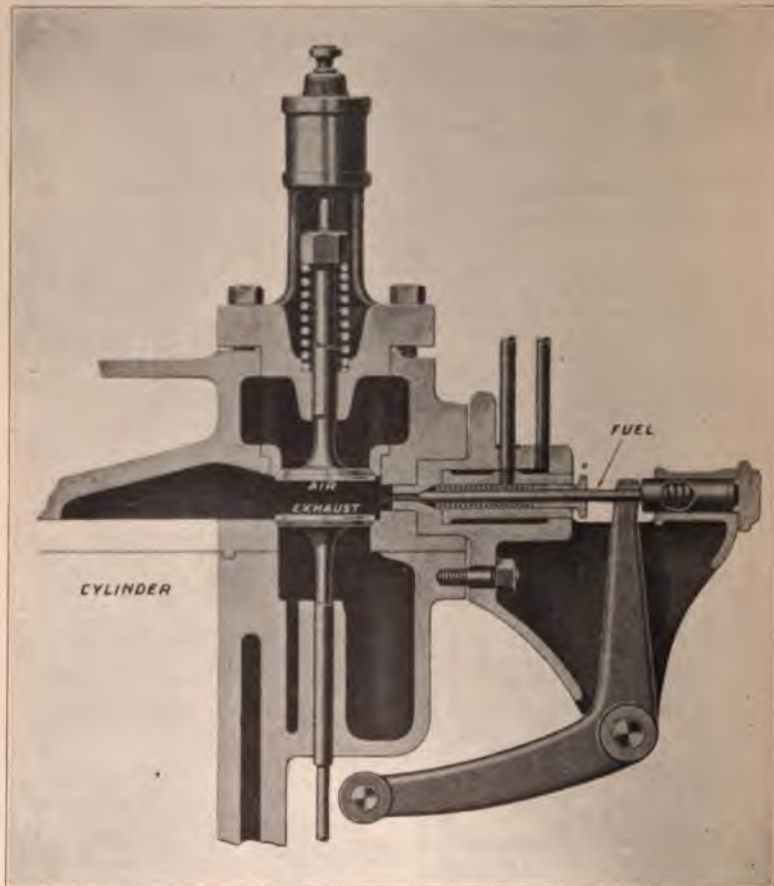


Fig. 81.

the explosive mixture being formed only with compression and heated by lamp only before starting.

VARIOUS VAPORIZERS DESCRIBED.

The Priestman type of vaporizer of class No. 1 is shown in Fig. 82. It consists of an outside shamber HH, having

THE USE OF CRUDE OILS, FUEL OILS, DISTILLATES, ETC.

suitable connections F and O, through which the exhaust gases from the engine pass. These gases heat the internal chamber M, to a suitable temperature required for vaporizing the fuel. The spray of oil is introduced at I while the air supply necessary for vaporizing the fuel is supplied at L.

WATER OUTLET TO CYLINDER

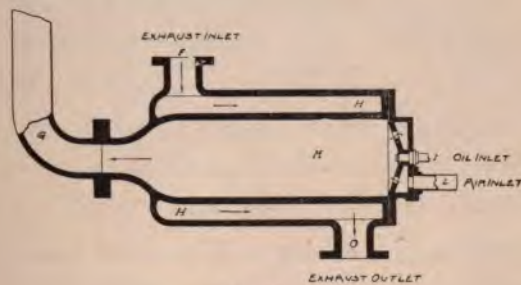


Fig. 82.

The spray of oil is formed by a sprayer shown at Fig. 83. The fuel is supplied by means of air pressure in the tank furnished by a small auxiliary air pump. Another oil sprayer somewhat similar to the Priestman is that of the Griffin

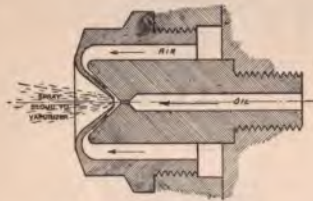


Fig. 83.

type. This is illustrated at Fig. 84 and works somewhat similar to an injector. Air enters through a passage shown in the center in the illustration and passing out of the orifice forms a partial vacuum in the annular space around it. This space is connected to the oil supply and thus the oil is drawn

THE USE OF CRUDE OILS, FUEL OILS, DISTILLATES, ETC.

Around this funnel is placed an outer casing with the space between them communicating with the upper passage in the vaporizer. At the end of the passage of the vaporizer nearest to the engine cylinder a valve is placed through which the vaporizer communicates with the cylinder. Fuel is injected in the lower part of the vaporizer as shown in the illustration and when in operation the valve is opened by a cam during the suction period of the piston. Heated air is drawn through the space around the inner funnel and into the vaporizer being heated on the way by ribs in the funnel. At the same time fuel is drawn into the vaporizer, where it mingles with the heated air and at the opening of the valve this oil vapor and heated air are drawn into the cylinder. A further supply

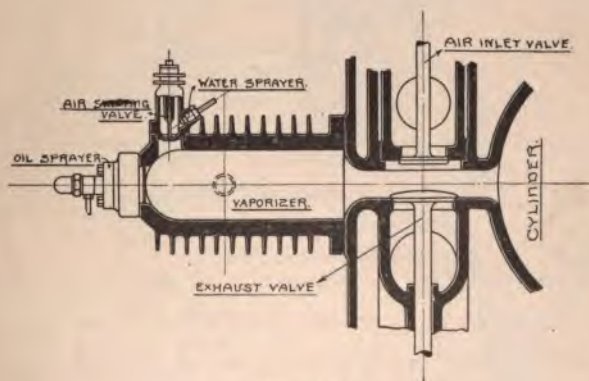


Fig. 86.

of air is drawn into the cylinder by a separate valve. Ignition is caused by metal tube heated by external lamp always burning.

Fig. 86 shows a later type Crossley vaporizer designed to use heavier fuels such as crude oil. It will be noted that it is somewhat similar to the Hornsby-Akroyd type in shape but unlike that vaporizer it is fitted with two inlets to it, one

GAS ENGINE PRINCIPLE AND PRACTICE.

for the fuel spray at the end opposite to the cylinder and another inlet also for water spray and air. By this arrangement the products of combustion are more easily exhausted from it. The ignition is caused by hot tube inserted in the side of the vaporizer and not shown in the illustration. The main supply of air is drawn through the air inlet valve placed directly over the exhaust valve.

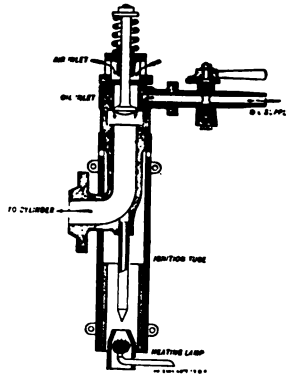


Fig. 87.

The Campbell type of vaporizer is shown in section at Fig. 87. This belongs to the third class above mentioned, all the air entering the cylinder passing through the vaporizing chamber, the oil supply entering with the air as shown in the illustration.

The heat necessary to cause vaporization is supplied by independent lamp shown under the vaporizer. This lamp also heats the igniter tube to the proper temperature to cause ignition of the gases. The air mixed with oil vapors being drawn into the cylinder by the forward movement of the piston during the suction stroke.

THE USE OF CRUDE OILS, FUEL OILS, DISTILLATES, ETC.

The type of vaporizer mentioned in class 4 is the Hornsby-Akroyd, already described in connection with the use of crude oil.

GENERAL REMARKS.

The above descriptions should be taken as of representative types only. Space does not allow of reference to the many kerosene engines now on the market in this country and in Europe. Amongst other kerosene engines which should be

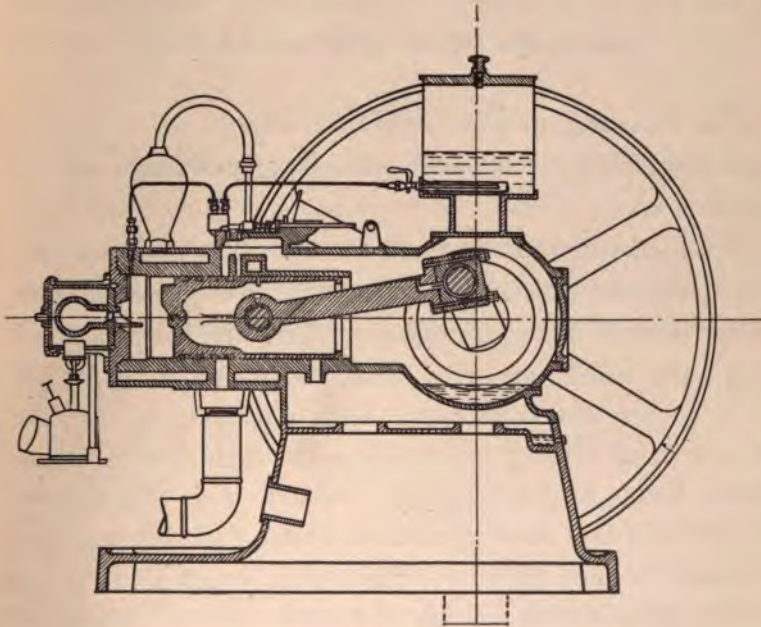


Fig. 88.

included are those in which the fuel is drawn into the cylinder with the air in exactly correct proportions, the heat of exhaust gases being used only to a partial extent for heating the fuel, the compression in the cylinder increasing the temperature while the ignition is caused by electric igniter. The

numerous engines of the two-cycle type of which the best known example is the Mietz and Weiss oil engine shown in section at Fig. 88, having the compression of the air effected in the crank chamber, should also be included. In these the fuel is injected either into the cylinder direct or into the passage for the air inlet thereto, causing partial vaporization which is continued during compression. Ignition being caused in a similar method to that described in class 4 or by electric igniter.

COMPARISON OF CRUDE OIL VAPORIZERS.

The following are some of the advantages and disadvantages of each of the different methods of utilizing crude oil referred to.

With the external vaporizer the advantage is obtained of having the fuel gasified before it enters the engine, thus when using crude oil having an asphaltum base and having constituent parts which cannot be burnt, the engine is maintained in a cleaner state and there is no possibility of deposits of any kind coming in contact with the valves or other mechanism. A disadvantage, however, with this type of vaporizer is that the vaporization of the fuel depends upon the heat obtained from the exhaust gases, and with a varying load it sometimes occurs that the temperature of the vaporizer falls so that if the load is quickly varied from a light to a heavy load, condensation may have taken place, and insufficient supply of vapor to take care of the quickly increased load may result, or the vapor may condense and be drawn into the engine cylinder in a liquid state. With some forms of these external vaporizers, devices have been attached

THE USE OF CRUDE OILS, FUEL OILS, DISTILLATES, ETC.

to take care of this defect, but they have tended to make the device somewhat complicated.

With the internal vaporizer referred to at "b," the simplest method of using crude oil is arrived at. As here, while the fuel enters the vaporizer of the engine in a liquid state, being there vaporized, any deposit which might come in contact with the piston rings or valves is formed in the vaporizer, and can quickly be removed. With the type mentioned at "c" highest thermal efficiency and therefore greatest economy is found. More complete combustion of the fuel is effected and less cooling water is required.

WATER INJECTION.

The injection of water into the vaporizing or combustion space has been introduced by several makers of oil and gas engines. With the injection of water or steam the temperature of the gases during compression is reduced and therefore higher compression pressure is allowable without pre-ignition being caused.

CHAPTER VII.

NOTES ON GAS PRODUCERS AND GASES.

As the subject of gas producers has become more and more important in recent years, no work relative to the gas engine, however elementary, would be complete without outlining the details of such apparatus explaining their operation and illustrating some of the leading makes. As such producers are now made of smaller units than formerly and as the economy of fuel effected by their use is so marked they have been brought largely into use in connection with the gas engine. Until the gas producer, especially of the smaller sizes, was made a commercial article, gas engines of small and medium power were almost universally operated, by burning illuminating gas. Thus, the gas engine could then only be employed in localities where illuminating gas was available. The advent of the producer has made the gas engine self-contained when used in connection with it and, therefore, its installation can now be made in any locality.

Until recent years, few persons have been acquainted with the manufacture of gas and even now the subject by many individuals is not understood, and the impression has gone forth from the appearance of the illuminating gas works that the process of gas making must be a very elaborate one, involving retorts where the fuel is heated and where the gas is liberated from it, necessitating purifiers, gas holders and other elaborate apparatus used in connection with it. The impres-

NOTES ON GAS PRODUCERS AND GASES.

sion has also obtained that the process of gas making is a dirty, smoky and objectionable one.

From the following descriptions it will be seen that the producer when used in connection with the gas engine is a very simple apparatus indeed, and the operation is a cleanly one.

COMPARISON OF STEAM AND GAS PLANTS.

The steam and the gas plant are similar in that coal or other combustible fuel and water are used in both. Heat is evolved from the fuel, which, with the steam engine plant, is burnt in the firebox of the boiler, this heat is conveyed by the steam to the cylinder of the steam engine, where it is allowed to expand and be transformed into work. With the gas plant—heat is evolved in the producer, which is conveyed to the gas engine cylinder in the form of gas, where it is burnt, from which heat is evolved, in the gas engine cylinder, and transformed into work.

The striking feature of the gas producer is its relative economy in comparison with the steam engine. It is well known that with steam engine installations from 5% to 12% only of the heat in the coal supplied to the boiler is transformed into work, whereas, with the gas engine plant 15% to 22% of the heat in the fuel supplied to the producer is turned into work by the gas engine. Among other advantages of the gas plant may be mentioned the absence of smoke and chimney, greater safety in operation (there is no fear of boiler explosions), the absence of trouble with hard water in the boiler, reduced standby losses, inasmuch as the producer consumes a very small amount of fuel when the engine is not in operation.

GAS ENGINE PRINCIPLE AND PRACTICE.

TABLE VIII. GASES. DENSITY, VOLUME AND AIR REQUIRED FOR COMBUSTION. (HERTZ)

Gas	Formula	No. of atoms	Atomic weight	Molecular weight O ₂ =32	Theoretical densi- ty, weight, or spec- ific gravity (water =1) at 0° C. 760 mm., 45° N. latitude at sea level in			Density referred to air=1	Specific volume at 0° C. and 760 mm.		Theoretical amounts required for perfect combustion.						
					grams of 1 liter, or in Kg. of 1 m ³		G lbs. of 1 cu. foot		Calcu- lated	m ³ gas per Kg.	Cu. ft. gas per lb.	Kg. oxygen per Kg. gas	Kg. air per Kg. gas, also per lb. gas	m ³ air per Kg. gas, also cu. ft. per cu. ft. gas	L	M	N
					F												
A	B	C	D	E			H										
Hydrogen	H ₂	2	1.008	2.016	0.00004	.00532315	0.00065	11.10386	177.896	7.4985	34.209	20.461	2.3827				
Oxygen	O ₂	2	16	32	1.42923	.0802215	1.1055	.069877	11.2077	—	—	—	—				
Nitrogen	N ₂	2	14.04	28.08	1.2512	.0782576	0.9701	.7967182	12.7621	—	—	—	—				
Carbon monoxide	CO	2	14	28	1.25058	.0780729	0.9673	.7946289	12.888	0.57143	2.4031	1.94321	2.3829				
Carbon dioxide	CO ₂	3	14.67	44	1.9652	.1228441	1.3201	.588541	8.15108	—	—	—	—				
Air (dry)	—	—	—	28.94	1.2928	.0807073	1.	.7785149	12.804	—	—	—	—				
Steam at 212° F.	H ₂ O	3	6.005	18.02	0.80466	.0502335	0.6212	1.242714	19.9003	—	—	—	—				
Methane (marsh gas)	CH ₄	5	3.206	16.03	0.71506	.044686	0.5539	1.386782	22.5734	3.9923	17.208	13.311	9.5299				
Acetylene	C ₂ H ₂	4	6.504	26.02	1.16197	.0725417	0.8098	.860585	13.7852	3.07504	13.254	10.252	11.913				
Ethylene (olefiant gas)	C ₂ H ₄	6	4.67	28.03	1.25201	.0781602	0.9684	.7967157	12.7941	3.4248	14.762	11.419	14.296				
Ethane	C ₂ H ₆	8	3.756	30.05	1.3421	.083785	1.0381	.7451086	11.9355	3.72787	16.086	12.427	16.679				
Ethyl alcohol	C ₂ H ₅ OH	9	5.116	46.05	2.05687	.1268342	1.50086	.4882329	7.78847	2.08469	8.96573	6.9506	14.296				
Allylene	C ₃ H ₄	7	5.72	40.03	1.78768	.1116172	1.38289	.558319	8.95698	3.1975	13.7823	10.6808	19.080				
Propylene	C ₃ H ₆	9	4.671	42.05	1.87801	.1172403	1.4527	.5324813	8.51851	3.42317	14.755	11.413	21.434				
Propane	C ₃ H ₈	11	4.005	44.08	1.96797	.1228568	1.52225	.5081378	8.13053	3.63141	15.6526	12.1076	23.827				
Butylene	C ₄ H ₈	12	4.67	56.08	2.50868	.1563161	1.93883	.3968723	6.89730	3.4249	14.7625	11.419	28.593				
Benzene (benzole)	C ₆ H ₆	12	6.504	78.05	3.4859	.217619	2.6884	.2968700	4.59520	3.07507	13.2546	10.2526	38.7405				
Carbon	C ₂	2	12.	24.	1.07193	.0669187	0.82915	.9328667	14.9435	2.66067	11.4943	8.8910	9.5505				

Exact atomic weight of H_2 equals 2.01526, and volume of one gram—molecule H_2 equals 22.3896 liters.

NOTES ON GAS PRODUCERS AND GASES.

TABLE IX. GASES. HEAT VALUES. (HERTZ)

Gas	Formula	Higher heat value of gas at 0° C. and 760 mm., or at 32° F. and 14.697 lbs. per sq. inch.						Latent heat of the water formed by combustion.						Lower or effective heat value of gas at 0° C. and 760 mm., or at 32° F. and 14.697 lbs. per sq. inch.					
		Calories per kg.		B. T. U. per lb.		B. T. U. per cu. ft.		Calories per m ³		B. T. U. per lb.		B. T. U. per cu. ft.		Calories per kg.		Calories per m ³		B. T. U. per lb.	
		O	P	Q	R	S	T	U	V	W	X	Y	Z	W	X	Y	Z	W	X
A	B																		
		34226	3082	61007	346.43	5420	488	9736	54.8	28806	2594	51851	291.57						
		2435	3045	4383	342.17	—	—	—	—	—	—	—	—						
		13318	9535	23973	1071.5	1360	975	2449	109.6	11658	856	21524	961.9						
Acetylene	C ₂ H ₂	12062	14015	21711	1574.8	420	488	736	54.8	11642	13527	20655	1520.						
		12169	15235	21904	1711.6	779	975	1402	109.2	11390	14293	20502	1602.4						
		12302	16631	22306	1838.7	1091	1464	1964	164.4	11301	15167	20342	1704.3						
Ethyl alcohol	C ₂ H ₅ OH	7237	14884	19027	1672.5	712	1464	1282	164.5	6525	13420	11745	1508						
		11677	20877	21000	2346	546	975	1098	109.6	11131	19002	20036	2236.4						
		11882	22316	21388	2337.7	779	1464	1403	164.5	11108	20852	19985	2343.2						
Propylene	C ₃ H ₆	12130	23853	21816	2630.4	991	1951	1784	219.2	11129	21902	27032	2461.2						
		11618	20912	20912	3299.	779	1951	1402	219.2	10839	27140	19510	3049.8						
		10242	35703	18435	4012.	420	1464	755	164.5	9822	34239	17690	3847.5						

NOTE.—Tables VIII and IX are based upon the atomic weights adopted by the International Atomic Weight Commission in 1903. The values of the first six gases are based upon the molecular heats of combustion obtained by Berthelot (1 kg. molecule H equals 69,000 Cal., CO₂ equals 97,650 'cal., 'CO equals 29,220 Cal.); the second six upon those obtained by Thomsen. None of the heat values are universally accepted as exact, but the values here given never differ more than 2 per cent. from any authorities and were expressly recalculated for this book.

GAS ENGINE PRINCIPLE AND PRACTICE.

While it is true that the first cost of the gas power plant is greater than that of the steam plant at present, the saving in operation quickly overcomes this disadvantage. The water consumed in the gas plant is about 15 gallons of water per actual horse power per hour, while with a non-condensing steam engine, only about 5 gallons per actual horse power per hour is required. In a condensing steam plant, however, at least 60 gallons will be necessary, unless the water is re-cooled. This is frequently done, both with the steam and gas plant, and then the consumption of water can be reduced to less than 2 gallons per actual horse power per hour.

GAS PRODUCER DETAILS.

The gas producer consists of a cylindrical, sheet iron vessel, lined with fire brick, to which the coal or other fuel used is supplied generally from the top. The fuel bed is purposely made deep, so as to give the gas an opportunity to develop by passing through the various zones of transformation.

The method of producing gas is very simple. Any combustible substance becomes gasified when heated to a high temperature and when oxygen is admitted it can be ignited and burnt.* The oxygen of the air combines with the gas generated from the hot coal, but if the supply of oxygen is insufficient or the temperature is too low, much of the gas goes to waste. It could, however, be collected subsequently and made to give off its full heat value by burning it with the necessary amount of oxygen. This is precisely what is carried out in the producer. The fuel is purposely gasified and mixed with a small amount of oxygen, together with super-heated

*According to recent investigations (Huetten), dry air contains by volume 21% oxygen, 78.06% nitrogen, and 0.94% argon; by weight, 23.2% of oxygen, 75.6% of nitrogen, and 1.2% of argon.

NOTES ON GAS PRODUCERS AND GASES.

steam, which is added in order to enrich the gas. The resulting mixture is a gas consisting chiefly of carbon monoxide (CO) and hydrogen (H), which passes from the producer towards the cylinder of the engine. In the engine cylinder, after passing through the process of cleaning and scrubbing hereafter described, this gas is mixed with the proper volume of air and is there compressed, ignited and burned. Thus, practically the total heat contained in the gas is then liberated and, expanding in the cylinder, performs work on the piston of the engine.

EFFICIENCY OF PRODUCER.

In the producer proper about 85% of the heat value of the fuel appears in the gas formed, while 5% to 15% of the heat is lost when starting and stopping the producer and is lost in the shape of unburned fuel. Thus, an efficiency of 70% to 80% may be taken as the average efficiency of the producer proper.

From each pound of coal burned from 65 to 75 cu. ft. of gas are obtained, having an average heat value of 130 B. T. U.'s per cu. ft., while also about one pound or 0.12 of a gallon of water is supplied in the form of steam to the producer. With some producers, notably the suction gas plant, where it is desired to keep down the temperature, frequently twice this amount of water is used. The gas leaves

FOOT NOTE.—The heat value of gases is measured by means of a calorimeter, in which apparatus the gas is allowed to pass through a small gas meter and then a pressure regulator, finally entering a cylindrical combustion chamber, where the gas is burned, the heat generated being absorbed by the measured quantity of water in a jacket surrounding the chamber. Temperatures of the gas and the water are registered by thermometers. The volume of gas burned being known and the weight of the water heated through a range of temperature indicated. The heat value of a cubic foot of gas is easily computed, one pound of water heated one degree Fahrenheit representing one British thermal unit. The value thus ascertained is known as the higher heat value of the gas. During the process of combustion in the calorimeter, the hydrogen in the burning jet combines with the oxygen and air and forms steam. In the calorimeter this is continuous and gives up its latent heat, which amounts at 32° F. to 1091.7 B. T. U. per pound of steam condensed. The value remaining is known as the lower heat value of the gas.

GAS ENGINE PRINCIPLE AND PRACTICE.

the producer at a temperature varying between 900° and $1,400^{\circ}$ F., and weighs from 0.068 to 0.075 lb. per cu. ft. For its complete combustion 0.95 to 1.1 cu. ft. of air at atmospheric pressure are required theoretically. After the producer has been freshly charged, the heat value of the gas sometimes increases to 150 B. T. U.'s per cu. ft. and then gradually falls to 120.

DIFFERENT TYPES OF PRODUCERS.

Every producer must be supplied with air and steam (preferably super-heated), and according to the method of their introduction to the bed of fuel, we distinguish three different systems of producers. These are known as

(a) The pressure gas producer, where air and steam are forced through the fuel bed by means of an injector or steam blast, the steam being generated in a separate boiler, the gas being forced into a gas holder where it is stored before being drawn therefrom to the engine;

(b) Suction gas producers, in which apparatus the air and steam is drawn through the producers and the gas aspirated by the movement of the engine piston. Thus, the vacuum in the engine's cylinder draws the gas generated through the various parts and pipes direct into the cylinder. In this apparatus the steam necessary is generated by the hot gas as it leaves the producer. No gas holder is necessary with this type.

(c) Combined suction and pressure gas plants. In this type the gas holder required with type "a" is reduced to a small pressure regulating gas receiver and the draught neces-

NOTES ON GAS PRODUCERS AND GASES.

sary is obtained by a steam jet or mechanically operated blower.

SUCTION GAS PRODUCER.

Owing to the diminished first cost and simplicity of operation, the suction gas plants are at the present time the most popular of those referred to. With this type of producer the steam boiler necessary with the pressure type is done away with and the fuel consumption is reduced. The amount of gas produced depends upon the suction or aspiration caused by the movement of the piston in the cylinder of the engine. Thus, if the load on the engine is diminished, the amount of gas drawn from the producer is also reduced, and the gas holder necessary with the pressure type of producer is not required. Where difficulties have been experienced with the suction producer operating with a varying load, these have been due largely either to faulty design or improper attention.

It would be thought that the work of drawing in the gas through the cylinder from the producer would be disadvantageous and would result in reducing the power developed by the engine, but as the pressure in the pipes between the producer and the engine is only equivalent to 4 to 8 inches of water below that of the atmosphere and being not in excess of barometric variations of the atmosphere practically no loss results.*

If the pipe connections between the engine and producer are too small or otherwise poorly designed, or if they are choked with soot, or the purifiers are packed too densely, in that case the resistance to the gas entering the cylinder may be greater and the power of the engine would be reduced.

*One standard atmosphere equals 14.7 lbs. pressure per sq. inch, or 29.92 inches of mercury column, or 33.95 feet of water column.

GAS ENGINE PRINCIPLE AND PRACTICE.

PRESSURE GAS PRODUCER.

The pressure producer gas plant was first placed on the market by J. E. Dowson of Great Britain, about twenty-five years ago and a large number of such plants are now in operation. Fig. 89 shows a pressure producer plant of modern design. It is put in operation by a fire started through the ash door of the producer, the flue valve in the pipe above being open to allow the smoke and gases generated at starting to escape to the atmosphere. In the steam boiler shown the pressure is raised to 40 to 70 lbs. per sq. in. This pressure varies with the size of the plant. It will be noted that the boiler has a closed grate and is fitted with suitable steam coils for super-heating the steam, that is, the temperature of the steam is raised above the temperature corresponding to its pressure in order to have it perfectly dry. After sufficient fuel, either anthracite or coke, has been placed in the producer, the ash doors are closed and the steam is allowed to enter same, passing through an injector or steam jet blower, thus, causing the air to enter with it under the grate of the producer. Test cocks are provided to try the quality of the gas. When the flame becomes a clear blue, having been first a dark red, it is of proper quality for starting the engine. The gas, before reaching the cylinder of the engine, passes through an air pre-heater and then through a feed water heater, which serves the boiler. The gas leaves the producer at a temperature of about 1000°F . but when it reaches the engine it is quite cool. The heat of the gas is partly given up to the air in the air pre-heater and in the feed water heater.

GAS SCRUBBER.

The temperature of the gas is further reduced by passing

NOTES ON GAS PRODUCERS AND GASES.

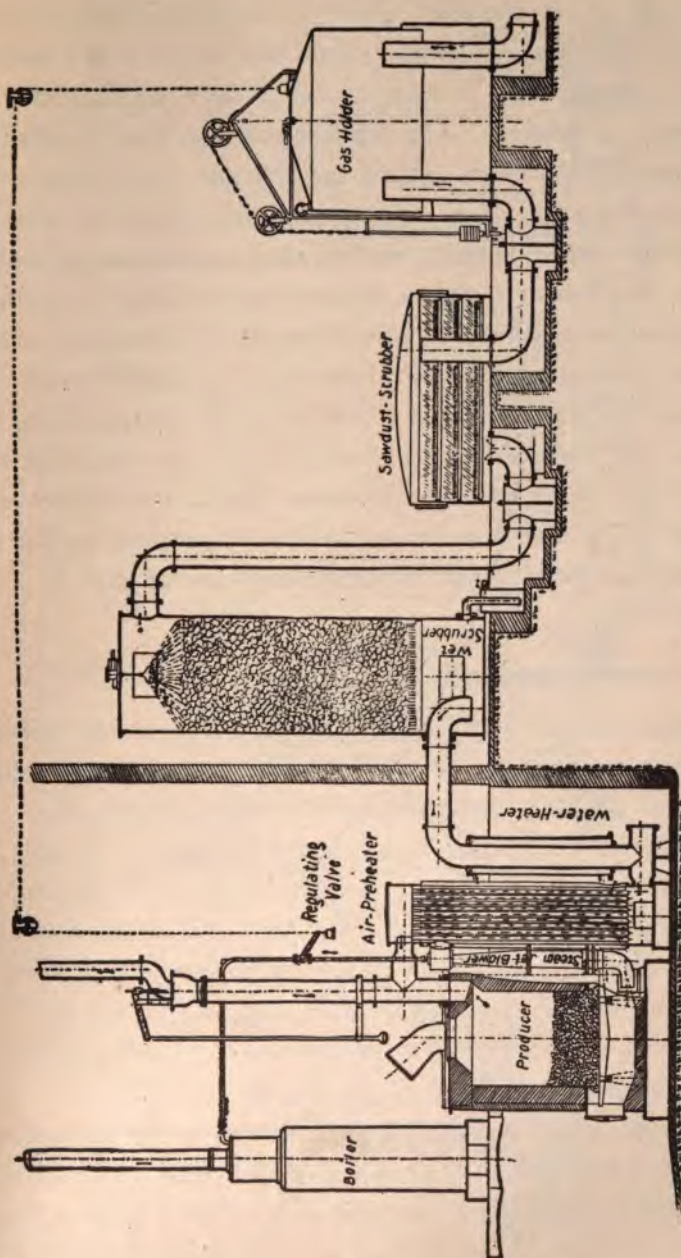


Fig. 89.

GAS ENGINE PRINCIPLE AND PRACTICE.

through a wet scrubber, which is a tall cylindrical vessel filled with coke. The gas enters this device at the bottom and rises through a bed of coke, over which water is allowed to trickle. The water used for this scrubber is frequently afterwards used in the cylinder water jacket. In the scrubber, the gas is cleaned from any substances, such as dust, etc., before entering the cylinder. After the gas passes from this washer it enters the sawdust scrubber or purifier. This device is a low box of cylindrical or rectangular shape having considerable area so that the gas can pass through two or more layers of sawdust at a slow speed, thus becoming filtered and deprived of its moisture. At the outlet of the scrubbers, water seals are provided, which, when filled with water, cause each vessel to be isolated, thus allowing for inspection or re-filling without unnecessary loss of gas.

GAS HOLDER.

From the scrubber the gas is conducted to the holder, which serves the purpose of an equalizer to overcome fluctuations of pressure caused by the suction of the engine. It also acts as a regulator on the steam jet blower. It will be seen from the illustration, Fig. 89, that this holder is equipped with a chain, attached at one end to a gas bell, which rises and falls with the increasing or decreasing pressure, the other end being connected to a valve on the blower. Thus, the discharge of air from the blower varies in accordance with the requirements of the load on the engine.

Fig. 90 shows a pressure plant similar to the one above described but without air pre-heater and steam boiler, which has been replaced by a fan, driven from the engine or by a separate motor. The attention required by the boiler is thus

NOTES ON GAS PRODUCERS AND GASES.

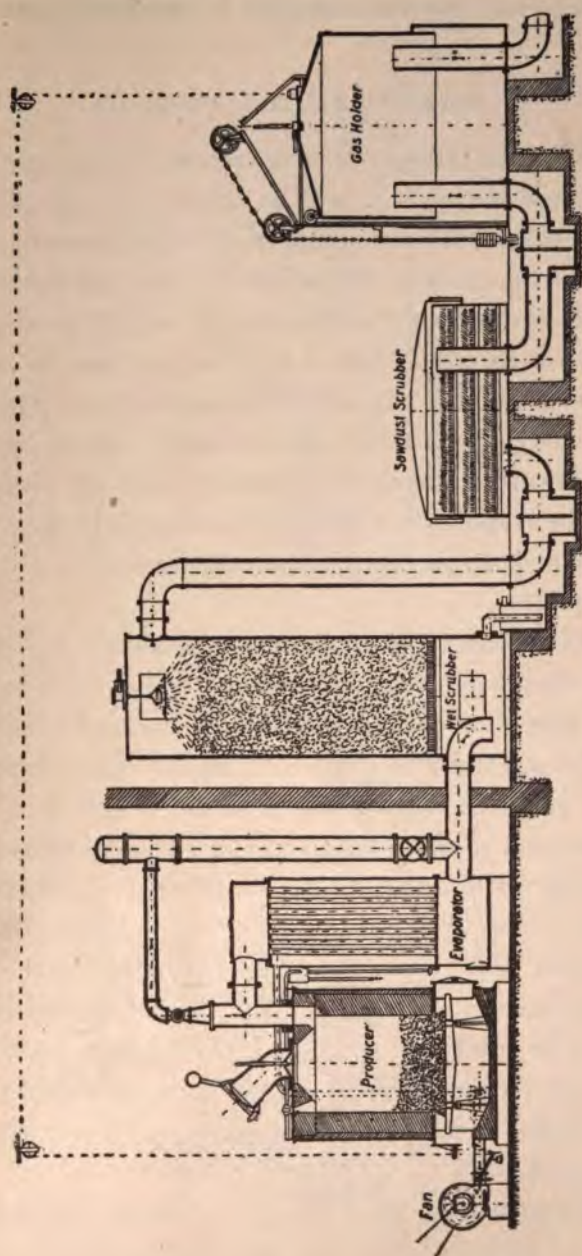


Fig. 90.

GAS ENGINE PRINCIPLE AND PRACTICE.

eliminated and the fuel consumed by the boiler is done away with.

KOERTING SUCTION PRODUCER.

Fig. 91 illustrates a complete suction producer gas plant in section and engine. It will be noted from the illustration that the difference between this type and the pressure producer shown in Fig. 90 is in the omission of the gas holder. The fan with the suction producer is only used at starting, being required to furnish a blast of air for a few minutes only. Its function is to bring the coals to an incandescent state. This fan is driven by hand or electric motor, where convenient. The illustration shows the Koerting type of producer, in which the evaporator is built close to the side of the producer. In some makes, this vaporizer or evaporator is placed directly over the fire.

It will be noted that all suction producers are provided with a charging device, which allows of the lid to be opened and a supply of coal emptied into it, without allowing the escape of gas from the producer. By this means loss of heat, as well as the entrance of excess of air, is avoided.

The construction of the vaporizer is clearly shown in Fig. 91 and the hot gas as it reaches the producer descends through the thin tubes and gives up heat to the water surrounding these tubes. If any quantity of dust is carried into these tubes, making them less efficient for the transmission of heat, the head of the vaporizer is removed and the tubes easily cleaned out. The frequency of cleaning of these tubes depends upon the fuel used and usually is not necessary oftener than about every six months.

The scrubber, in which the gas is cooled and cleansed, is shown in Fig. 91. In plants of less than 50 horse power

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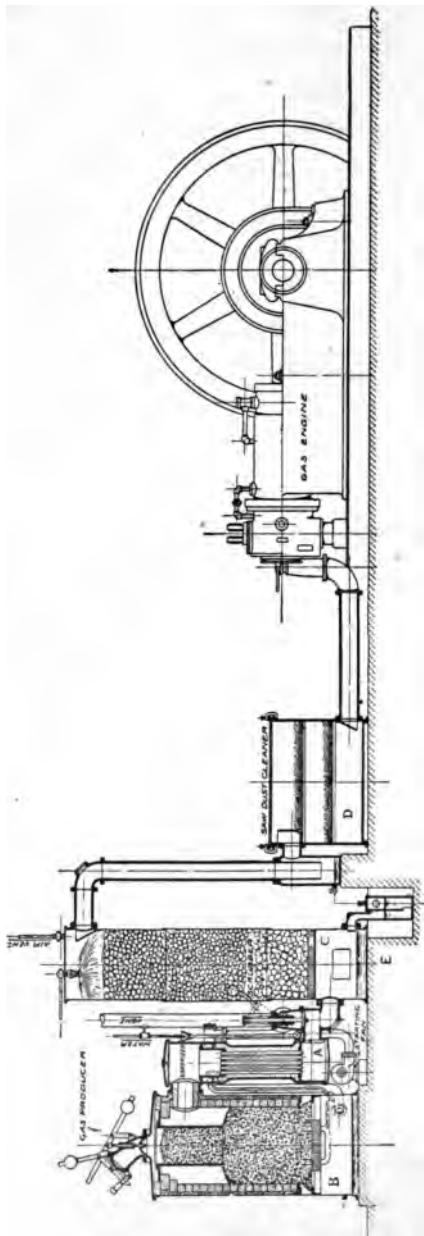


Fig. 91.

GAS ENGINE PRINCIPLE AND PRACTICE.

the sawdust purifier, shown at D is not required and can be replaced by a moisture separator, which occupies less space and is cheaper in first cost.

To prevent the formation of bridges in the producer, and the formation of clinkers in the deep bed of fuel, it becomes necessary to occasionally break up these obstructions, and for this purpose, holes, covered by sliding lids, are provided in the furnace doors (see Fig. 91.) The water to be evaporated is maintained at a constant level inside the vaporizer, entering from an open box, shown on the other side. At the upper part a space is provided for pre-heating the air. Both steam and hot air are thus drawn down to the bottom of the producer. The scrubber, which in most cases is filled with coke, in this instance consists of a large number of wooden slats, maintained in a wet condition by the cooling water trickling down them. The basin at the bottom of the scrubber is provided to allow sediment to collect which can be removed while the scrubber is in operation. The level of the water is usually about twelve inches above the outlet of the gas pipe, thus preventing leakage.

PINTSCH SUCTION PRODUCER.

Fig. 92 illustrates a "Pintsch" suction gas producer. It will be seen that the essential feature of this type is the automatic pressure regulator. The spring "G" is in tension and tends to maintain the dome F in an inflated condition. Thus, when the engine draws in a portion of gas from the regulator, the atmospheric pressure depresses the dome which is lifted again by the force of the spring. This action takes gas from the producer. Thus, instead of the aspiration of the gas taking place during the charging stroke of the engine, the

NOTES ON GAS PRODUCERS AND GASES.

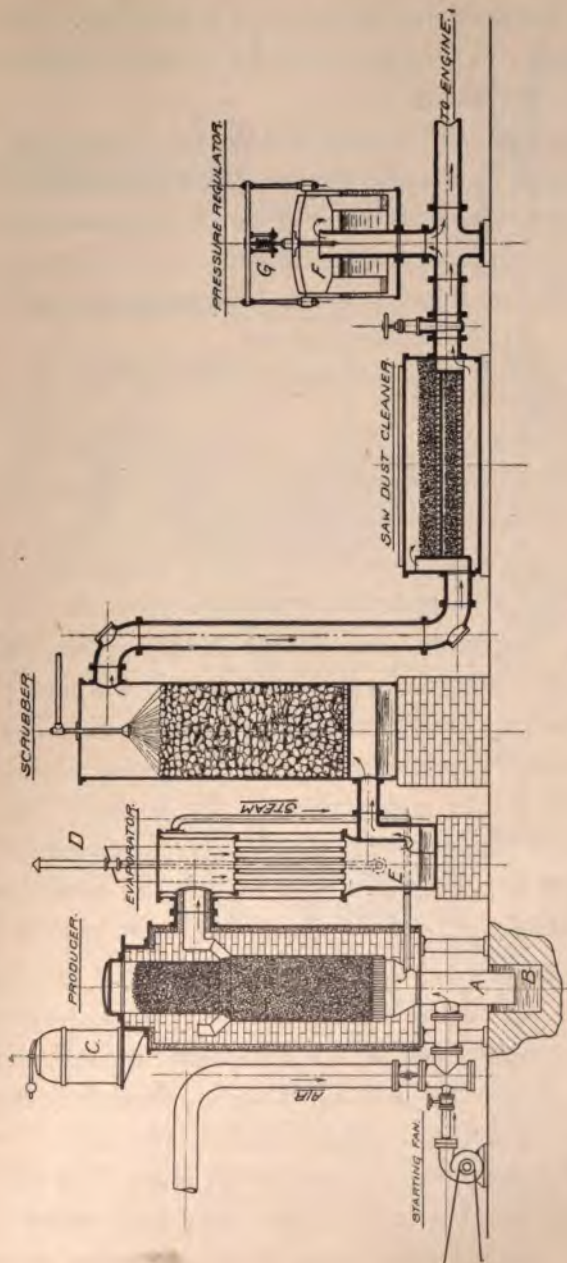


Fig. 92.

GAS ENGINE PRINCIPLE AND PRACTICE.

action of suction from the producer is practically continuous. The amount of lift of the dome F is varied by regulating the tension of the spring "G."

The ash tube "A" dipping into the water sealed ash trough "B" is shown in the illustration, as is also the filling hopper "C" and its closing cover. "D" is the flue used at starting, which allows the smoke to escape. "E" is a trap, which, when filled with water, prevents the passage of gas.

WILE AUTOMATIC PRODUCER.

Fig. 93 shows the "Wile" automatic gas producer in section. This type combines many of the advantages of the suction type as well as those of the pressure producer. L is a regulating gas receiver or holder which is much smaller than that required with the ordinary pressure type. As will be seen from the illustration, it is fitted with three pipes, being M, a gas outlet to engine, a gas inlet pipe J, and also a return pipe G leading back to the water seal box E. The gas is drawn from the producer by a steam ejector F and forced through the cooler and scrubber to the holder. The return pipe from the holder is fitted with valve K, closed by a lever actuated by a projection on the holder. In operation when the holder is in the lower position the return pipe G is automatically closed and the ejector F draws the gas from the producer. When the holder rises the valve K is opened and the ejector then allows the gas to circulate through the return pipe till the holder is lowered again, thus the proper gas supply to the holder is automatically controlled. On reference to Fig. 93 it will be seen that A is the feed water tank elevated so as to obtain sufficient head or pressure to automatically feed the steam boiler B which operates the ejector.

NOTES ON GAS PRODUCERS AND GASES.

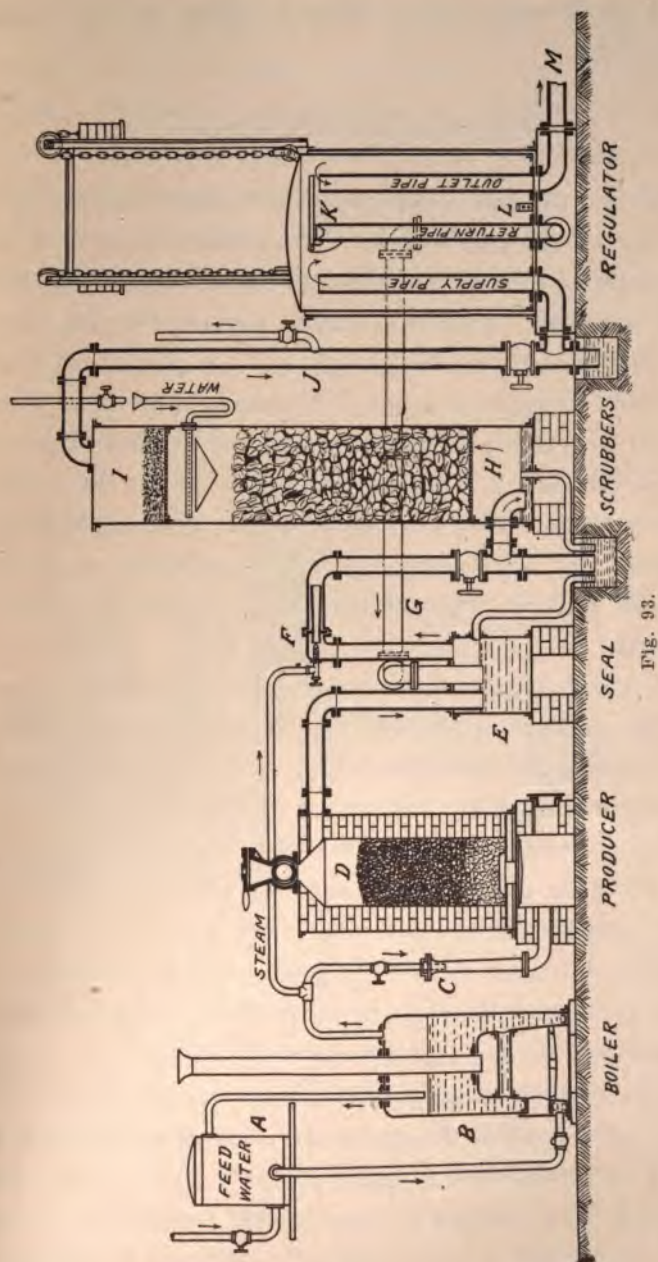


Fig. 93.

GAS ENGINE PRINCIPLE AND PRACTICE.

D is the producer; the scrubber is shown at I having water seal at H.

PRODUCERS FOR BITUMINOUS COAL.

All the producers previously shown are intended for use with anthracite coal or coke. If bituminous coal is used, it is necessary to pass the gas through tar extractors, usually consisting of rotary washers. The tar contained in soft coal must be eliminated before the gas enters the engine. Such washers, of course, require extra power to operate them and a plentiful supply of water, and the heat contained in the hydro-carbons of the tar are lost. A better plan is to convert the tar vapors into permanent gases in the producer, drawing them down through the incandescent coal for reduction or for combustion with air, whereby the heat generated is given up to the gas.

A disadvantage experienced with this producer is the trouble in starting, therefore such producers are frequently left burning almost continuously. It has also been found necessary to design the evaporator to take care of varying demands for steam, so that should the zone of incandescence in the producer shift, thereby allowing the tarry vapors to escape dissociation, the moisture in the fuel would become so great that little or no steam is required in the producer. The evaporator must therefore be adapted to varying requirements of steam.

Fig. 94 shows a producer designed for use of brown coal. It will be seen that the evaporator consists simply of a water pan under the grate. In addition to the regular grate there is also a grate at the side of the producer for cleaning and to be used in starting. A small fan, not shown in the illustration,

NOTES ON GAS PRODUCERS AND GASES.

furnishes air to both grates when starting up. In other respects, this outfit is the same as the ordinary suction producer. The gases, however, with this type of producer are taken from the hottest zone of the fuel in the producer instead of from the top as usual, in this way the tarry vapors are compelled to pass through the hot bed of fuel and become decomposed. No vaporizer is necessary because of the high percentage of moisture in the brown coal.

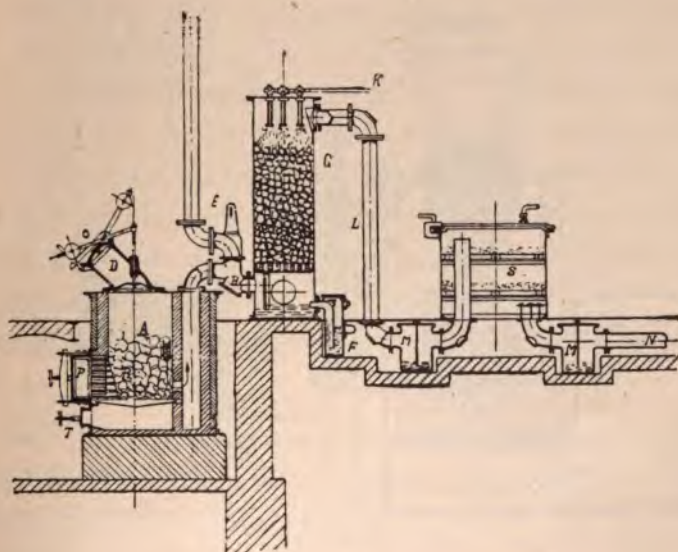


Fig. 94.

Fig. 95 shows in section the producer made by the National Gas Engine Company, of Ashton under Lyne, England. This producer is similar, in many respects, to those already referred to. One of its chief features is the method of introducing the air into a helical passage surrounding the pipe carrying off the hot gases from the producer to the scrubber.

GAS ENGINE PRINCIPLE AND PRACTICE.

The water is introduced into a type of field tube placed in the centre of the gas pipe leading to the scrubber and emerges heated into the funnel leading into the annular space in which the hot air is circulating. The water is held by various ribs in this space so that the air becomes thoroughly saturated before it flows along the air and steam pipe surrounding the producer from whence it is drawn into the space below the grate and through the fire in the regular way.

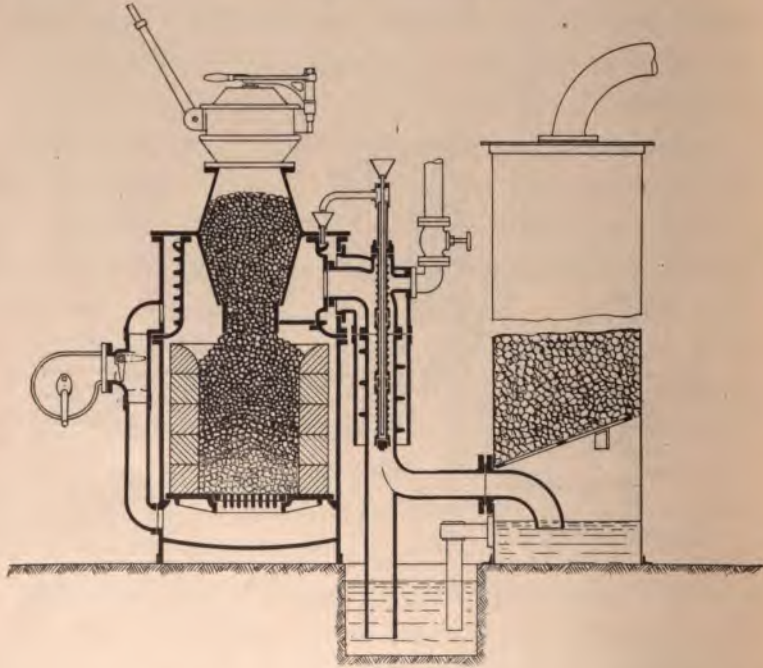


Fig. 95.

PROPORTIONS OF GAS PRODUCERS.

The following may be taken as average dimensions for grate surface.

25 lbs. of coal per sq. ft. of grate surface yields 60 cu. ft. of gas per pound of coal.

NOTES ON GAS PRODUCERS AND GASES.

One sq. ft. furnishes $25 \times 60 = 1,500$ cu. ft., which is sufficient for a 15 actual horse power engine.

Accordingly, 0.066 sq. ft. of surface is required per B. H. P. With coal finer than pea, the grate surface may be made 20% larger in order to obtain sufficient area for the air to pass through it. For coke or very poor fuel, 0.1 sq. ft. should be allowed per B. H. P.

The height of the bed of fuel depends chiefly upon the frequency of charging. If the producer is charged with coal every five hours, it should have a capacity for 25 lbs. $25 \div 15 = 1.667$ lbs. $\times 5$ hours $= 8.34$ lbs. of coal per B. H. P., $8.34 \div 50 = 0.1667$ cu. ft., $\div 0.066$ sq. ft. grate surface requires 2.52 ft. as depth of the fuel bed. It is found advantageous to have the fuel bed high; otherwise, the gas will be imperfect and air might pass through it unburnt into the upper part of the producer together with carbon monoxide, which has not been reduced, and mix with the gas there, allowing some of it to burn. In cases where heavy fluctuations may be expected, a large producer space is also advisable.

FIRE BRICK LINING OF PRODUCERS.

The lining of the producer requires very careful attention and interlocking fire brick is best, a space of about one inch being left between the iron shell and the brick lining, which is filled up with fine ashes. This is necessary to reduce the loss of heat or the passage of air. The openings should be one-fourth to three-eighths inches wide, when the flat grates are used. When very small coal is used, super-imposed grates are necessary. When using wood or charcoal, no grates are necessary.

GENERAL REMARKS.

The fan or blower in small plants up to 50 horse power

GAS ENGINE PRINCIPLE AND PRACTICE.

should have a capacity of 175 cu. ft. of air per minute. With larger plants, a capacity up to 700 cu. ft. should be provided.

The coke scrubber should not be less than 0.7 cu. ft. per B. H. P. in volume. Frequently, 1 cu. ft. per B. H. P. is used. The depth should be 2.5 to 3 times the diameter of the scrubber. The water spray must be arranged so that its outlets will not clog and should be made easily removable for cleaning. The water supply should be visible. The trap at the bottom of the scrubber should be such that twelve inches of water can be allowed for properly cleaning and preventing odor from the dirty scrubber water.

The dry purifiers are either cylindrical or oblong tanks of such area that the speed of the gas in passing through the two to four layers of filtering material will be slow. Sawdust is preferred for this purpose, provided sufficient area to diminish the resistance to suction is furnished. The volume of the purifiers should not be less than 0.4 to 0.6 cu. ft. per B. H. P. In some cases where room is not available, the dry purifier is placed on top of the wet purifier. In other instances, the dry purifier is supplemented by a tar separator, same being a cylindrical box having a vertical partition, against which the gas impinges at great velocity. This partition is made easily removable for cleaning.

It is essential that the connecting pipes between the various parts of the gas making plant be as short as possible and with the least number of bends. Each bend should have a removable door or plug for the removal of dust and other matter which may accumulate. A vent pipe with stop valve, connected to the gas main close to the engine, should also be provided to allow the system to be emptied of air and poor gas at starting.

CHAPTER VIII.

INSTALLATION. UTILIZATION OF WASTE HEAT.

Many internal combustion engines prove unsatisfactory in operation because precautions have not been taken to insure proper installation. Not infrequently the work that the engine has to perform has been underestimated and then when overloaded continually a gas or oil engine quickly gives trouble. The normal load on an engine should not be greater than 90% of its rated maximum capacity. In this way a margin of power is in reserve for contingencies arising, such as heated bearings and other losses of power and which is sufficient to overcome any additional temporary increased load that has not been provided for.

The chief features of proper installation, are :

- a. Building of foundation.
- b. The arrangement of exhaust and air inlet piping.
- c. The arrangement of proper cooling water supply.
- d. Means of transmission of power.

FOUNDATION.

The foundation is shown at Figs. 96, 101, 102. It is more frequently built of a shape as there shown. Concrete is universally employed for this purpose. It is essential that the concrete be of the proper ingredients,—the following are sometimes recommended :

3 parts of stone.

GAS ENGINE* PRINCIPLE AND PRACTICE.

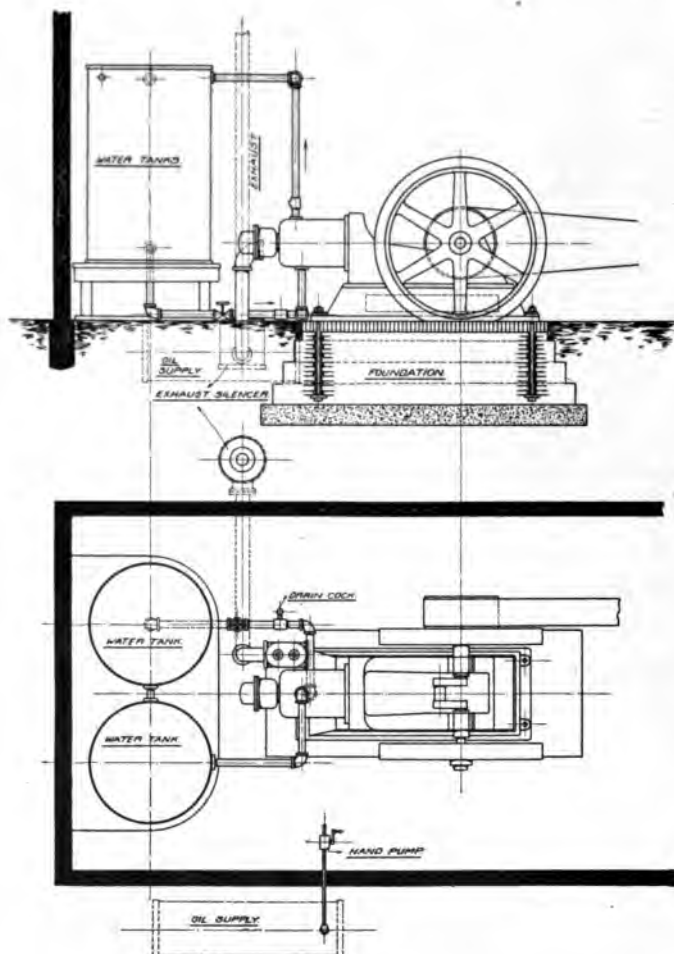


Fig. 96.

INSTALLATION. UTILIZATION OF WASTE HEAT.

3 parts of sand.

1 part of Portland cement.

It is necessary that the foundation be built on solid ground. If it is to be placed on ground that is spongy or where water is present, piling under the foundation is of course necessary. Foundation drawings are always supplied by the makers of the engines and usually $8\frac{1}{2}$ cubic feet per horse power of the engine is found sufficient. The essential feature of a foundation is its weight. The foundation bolts which attach the engine to the concrete foundation are shown in the illustration. For smaller size engines up to 15 horse power, the foundation is sometimes formed by heavy timbers placed lengthwise underneath the engine embedded in the ground or in concrete as shown in Fig. 100. Figs. 101 and 102 show the installation of gasoline engine with fuel tank and connections.

In order that the engine may work properly it is necessary that its reciprocating parts be as effectively balanced as is possible to accomplish with a gas engine having infrequent impulses.

In some cases the engine has to be placed on the upper floor of a building in that case it is bolted to the timbers in the usual way but except in the case of the smaller engines and those of a slow speed considerable vibration may be experienced unless the flooring is built to withstand such vibration.

EXHAUST PIPING.

A general arrangement of a larger size gas engine with water cooling tower, exhaust silencer, gas supply, air inlet, and exhaust piping is shown in Figs. 97, 98, 99. This pipe is

GAS ENGINE PRINCIPLE AND PRACTICE.

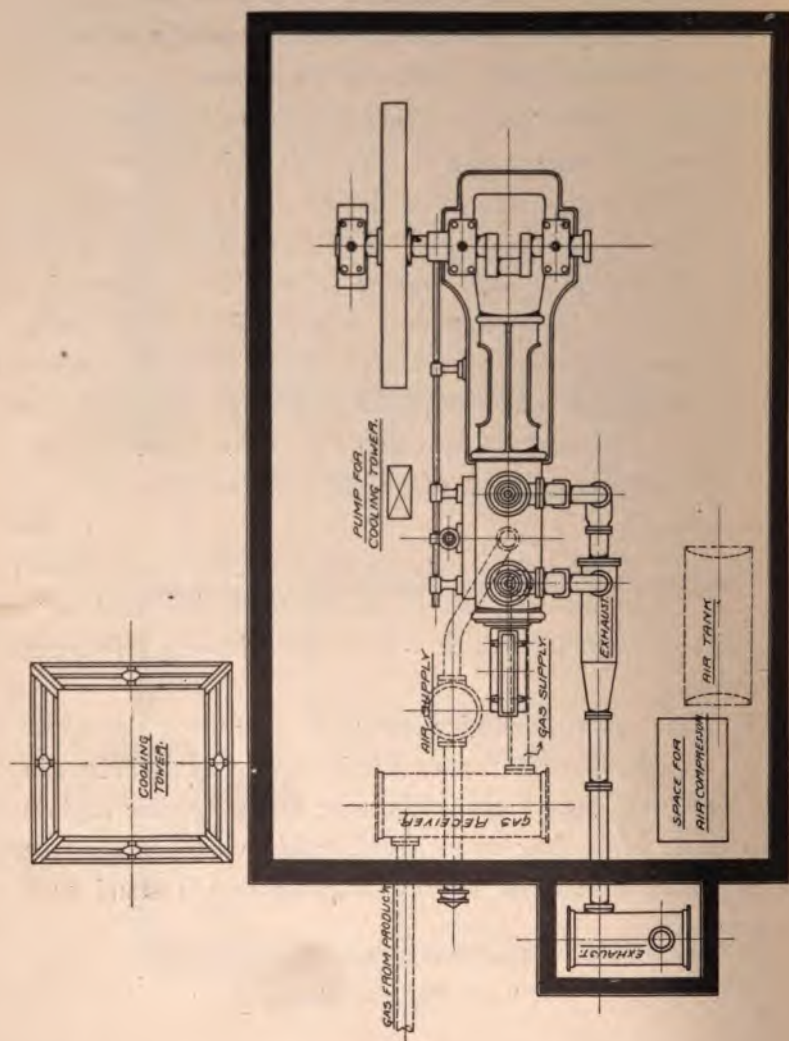


Fig. 97.

INSTALLATION. UTILIZATION OF WASTE HEAT.

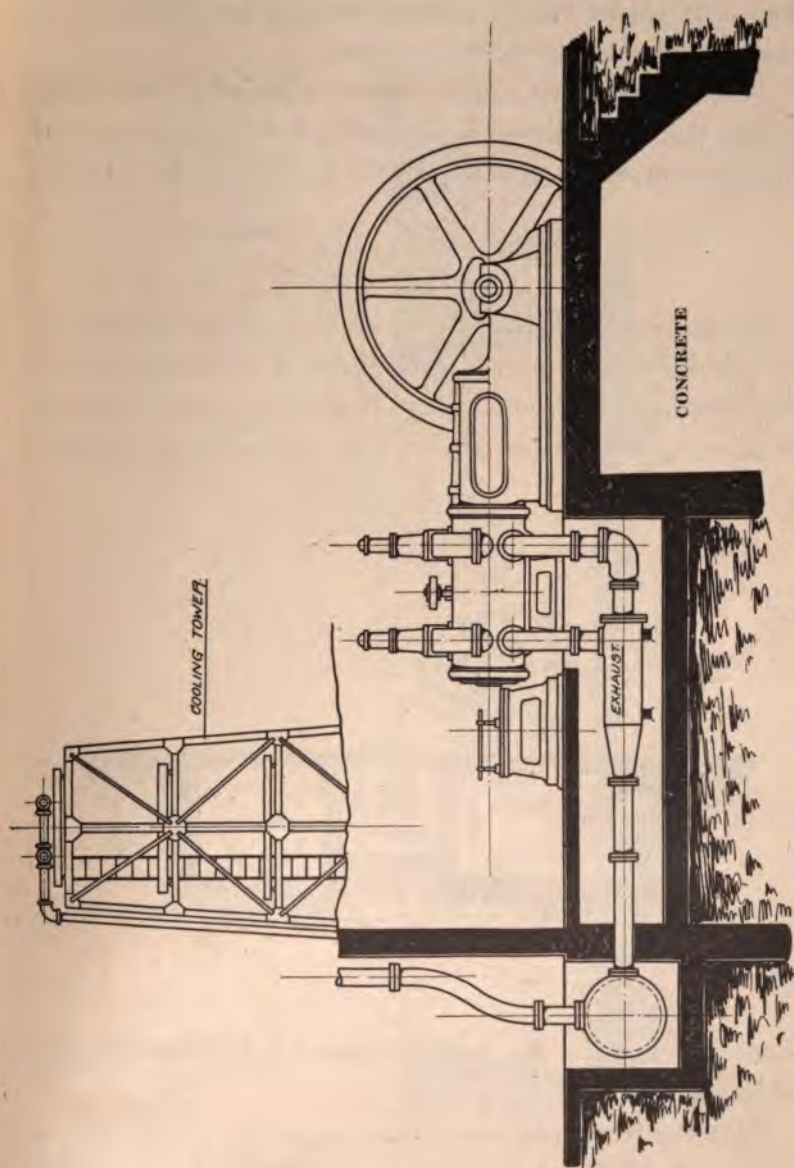


Fig. 98.

GAS ENGINE PRINCIPLE AND PRACTICE.

usually of 0.28-0.35 times the diameter of the cylinder of the four-cycle engine and of sufficient area to avoid choking or back pressure during the exhaust period.

With the two-cycle engine where the period of exhausting is very much less than with the four-cycle engine, the area of the pipe is usually 0.35-0.4 times the diameter of the cylinder.

EXHAUST SILENCER.

As the exhaust gases are emitted from the cylinder at considerably above atmospheric pressure, it is essential that they be properly silenced. Fig. 103 shows various methods of silencing the exhaust gases. The purpose of the exhaust

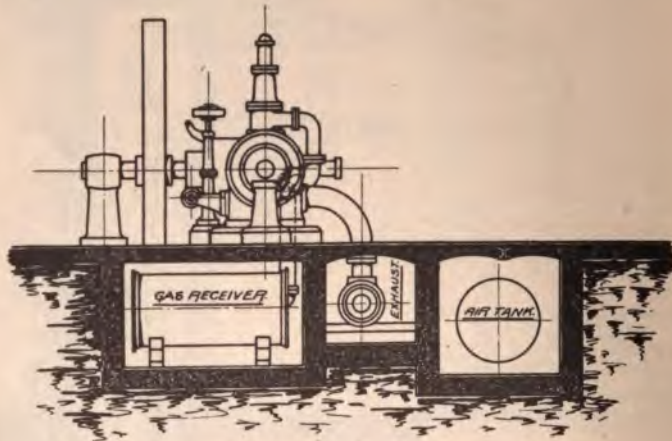


Fig. 99.

silencer is, to allow the gases to expand before reaching the atmosphere.

With the larger engines of some makes the exhaust pipe is water-jacketed between the engine and the exhaust muffler or silencer.

INSTALLATION. UTILIZATION OF WASTE HEAT.

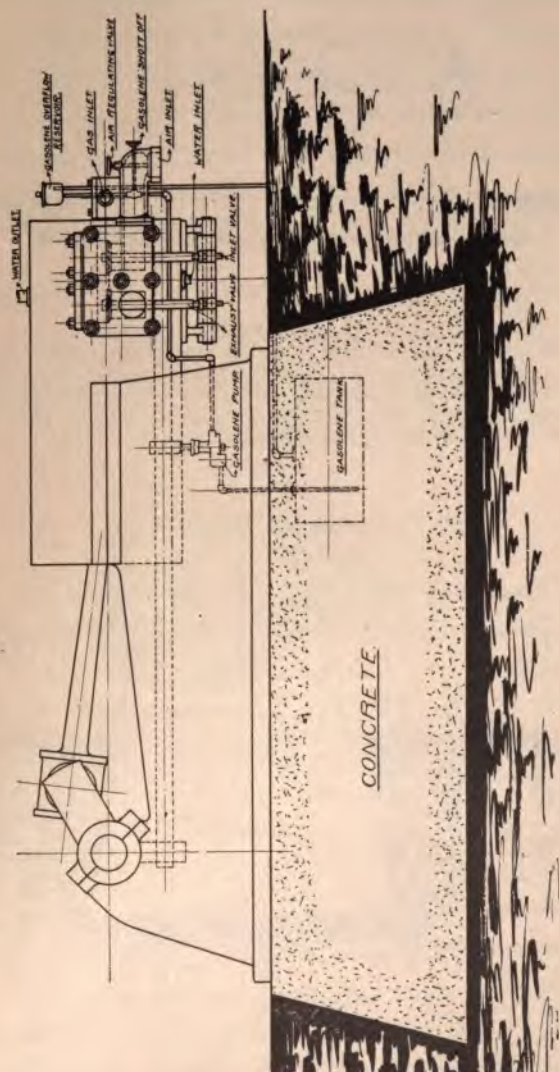


FIG. 101.

GAS ENGINE PRINCIPLE AND PRACTICE.

Various materials are employed for the exhaust pipe. Where water is injected into the exhaust pipe, which is done so as to cool the exhaust gases, thus reducing the volume,

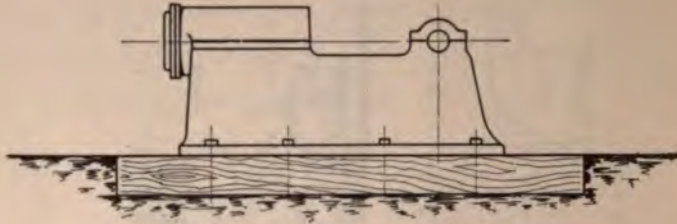


Fig. 100.

ordinary wrought iron pipe has to be frequently renewed, and other material such as cast iron or vitrified pipe carefully jointed has been advantageously used.

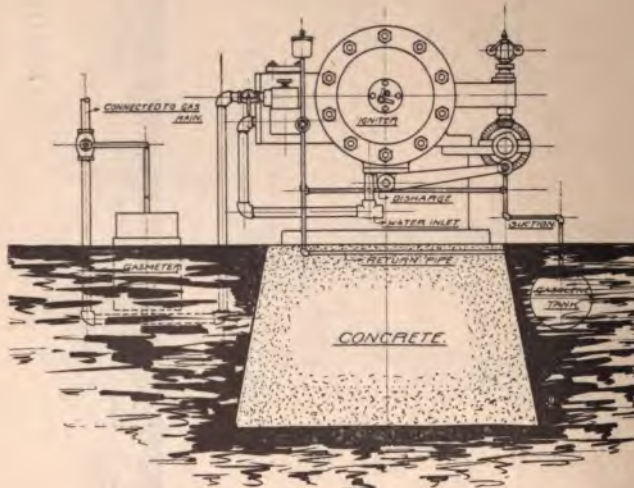


Fig. 102.

The exhaust silencer should be from 5 to 8 times the engine cylinder in cubical contents. In some cases water is injected into the exhaust pipe close to the outlet from valve

INSTALLATION. UTILIZATION OF WASTE HEAT.

box, thus the gases are cooled and consequently the volume is decreased and the noise at outlet reduced. Pits filled with large stones form an efficient silencer, care being taken that the covering of the pit is properly secured. Amongst other silencing devices the exhaust pipe with slots cut in it and expanded to increased diameter at its outer end and the pit made V-shaped as shown in Fig. 103 may be mentioned.

SILENCING AIR INLET.

Silencing of the air suction is frequently effected by taking the air from a wood or metal chamber as shown in Fig. 104 where the air passes through small apertures preferably lined with rubber to this chamber before it is drawn into the cylinder.

CYLINDER COOLING WATER.

All internal combustion engines (except those of the smaller size) require cooling water to circulate around the cylinder. For this means an aperture between the inner and outer cylinder wall is arranged and is known as the cooling water jacket. Through this chamber water is passed, taking up the heat as explained in Chapter I and maintaining the cylinder and piston at a proper temperature to avoid over expansion and to preserve proper lubrication.

As explained in Chapter I 30% to 40% of the total heat evolved in the engine cylinder is lost in the water jacket. In practice, the amount of water required at the ordinary temperature (70° F.) to cool the cylinder, is 7 to 10 gallons per actual horse power per hour. With the smaller size engines cooling water tanks, as shown in Fig. 96 are usually employed, the water circulating by gravitation. Then, in continuous

GAS ENGINE PRINCIPLE AND PRACTICE.

operation, all the water in the tank becomes heated and is allowed to cool off during periods when the engine is at rest. The capacity of the tank should be 70 to 100 gallons per B. H. P. of engine. If engines are required to run continuously without stopping, of course, other means of supplying the cooling water must be furnished. In those cases the water is either taken from the main or other supply and al-

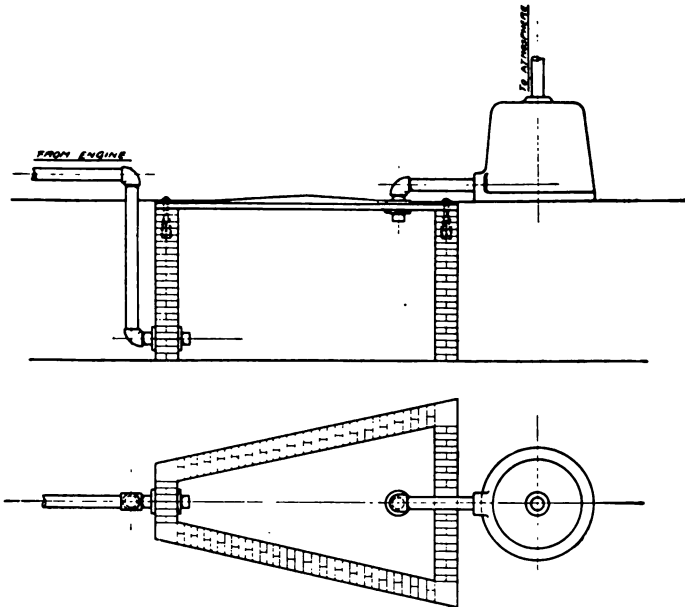


Fig. 103.

lowed to run to waste or a cooling tower, as shown in Fig. 97 is used, which allows the temperature of the water to be suitably reduced and then the amount of water consumed is only that due to evaporation.

With the larger gas engines the cooling becomes more important as not only are the cylinder walls cooled but the cylinder head, pistons, piston rod as well as in some cases the

INSTALLATION. UTILIZATION OF WASTE HEAT.

inlet and exhaust valves are arranged with water circulation. In this case it is customary to circulate the water by pump either directly attached to the engine itself or operated by independent motor, the system of gravitation from tanks described for use with the smaller engines being not suitable on account of the many pipe connections required and the pres-

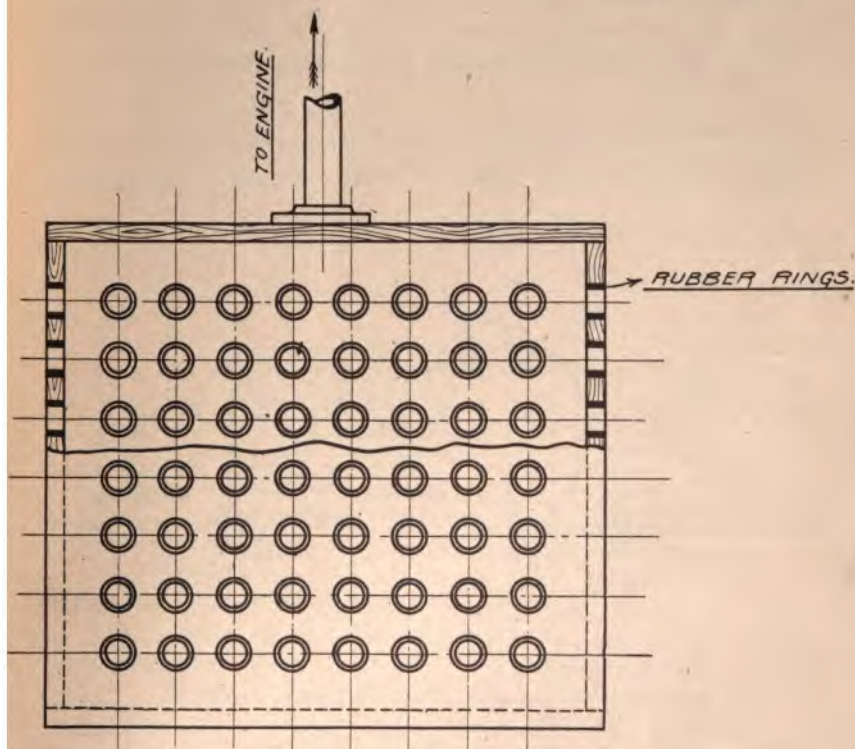


Fig. 104.

sure necessary to properly circulate the water. With large engines with the various parts cooled each should have a separate pipe connection each controlled with its separate valve and with separate outlet so that the proper temperature can be maintained on each part and by means of the open outlet

GAS ENGINE PRINCIPLE AND PRACTICE.

any stoppage of the flow of water can be at once detected by the attendant. A valve in the main water supply controlling all connections is also required for use in case of emergency. The use of the cooling tower referred to allows use of rain water or that free from lime and other solids which in some localities would cause trouble by deposits being formed in the different water jackets.

THE UTILIZATION OF WASTE HEAT FROM GAS ENGINES.

With the installation of internal combustion engines (frequently taking the place of steam engines) the matter

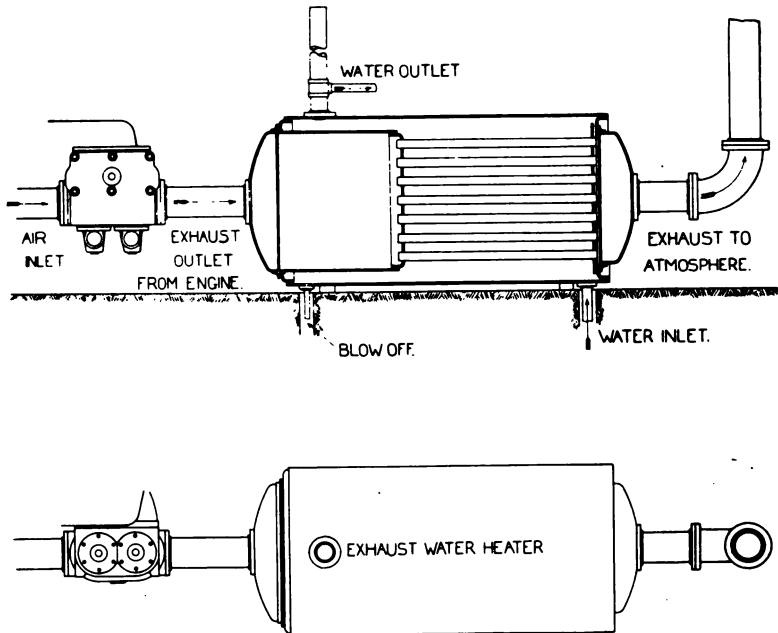


Fig. 105.

of heating the building has to be considered and the question of utilizing the waste heat from the exhaust gases and the

INSTALLATION. UTILIZATION OF WASTE HEAT.

cylinder jacket cooling water with all the larger engines, is frequently taken up.

The following tables show the amount of heat available for this purpose. It should be remembered that, unlike the steam engine, with the gas engine heat only is available when the engine is in operation and therefore an auxiliary means of heating the building will be also necessary. This is frequently supplied either by a low pressure steam boiler and separate radiating apparatus or the heat required when the engine is stopped is supplied by a separate water heating boiler in connection with the radiating system of the exhaust gas heater.

The heat balance of the gas engine shows the following conditions:

TABLE X.

GAS ENGINE AND PRODUCER PER ACTUAL HORSE POWER PER HOUR.

	B. T. U.		B. T. U.
Supplied to producer		Heat equivalent per	
1 lb. of coal containing 14,000 B. T. U., efficiency of producer being 75 %.		I. H. P. from indicator card, 2,545	
Supplied to engine	10,500	B. T. U., mechanical efficiency 85 %.	
		Heat equivalent per B. H. P.=	
		$2,545 \div 0.85 =$	2,994
		Heat lost in water jacket, 30 % =	3,150
		Heat lost in exhaust 35 % =	3,675
		Radiation and other losses 6.49 % =	681
	10,500		10,500

GAS ENGINE PRINCIPLE AND PRACTICE.

With the average gas engine when operating at full load it is obvious that we have $3150 + 3675 = 6825$ B. T. U. actually available from cooling water and exhaust. If the efficiency of the exhaust heater is 68% which it is fair to assume would be so, then $3675 \times 0.68 = 2,500$ B. T. U. would be taken up by the water in passing through it and allowing for the loss of water in vaporizer of producer then 5550 B. T. U. should be actually available.

From this it will be noted that in order to completely utilize the waste heat from the engine, it is necessary to take up the heat lost in the water jacket, as well as that discarded in the exhaust. This can be best accomplished by passing the water issuing from the cylinder, which will flow out at a temperature of 100° to 140° through an apparatus, such as that shown at Fig. 105, or other apparatus of somewhat similar description, which will offer ample surface for the heat of the exhaust gases to be taken up by the water passing through tubes as shown, the water would be heated to a temperature of about 160° to 170° F. The amount of water that it is possible to raise in this way will vary according to the design of the engine and the amount of cooling surface of the cylinder and would be from 65 to 120 lbs. per horse power per hour. The amount of heat available for heating, of course, further depends upon the efficiency of the exhaust gas water heater.

METHODS OF UTILIZING HEAT.

There are several methods of utilizing this heat, three of which may be mentioned here:

- a. Heating by water circulation;

INSTALLATION. UTILIZATION OF WASTE HEAT.

b. Indirect system of heating by means of heated air by blower from heated water pipes, and

c. Steam heat.

With the first arrangement sufficient lengths of piping would have to be furnished and sufficient surface to allow the water to give out its heat.

The second arrangement would be most advantageous, the air would be warmed with sufficient lengths of piping take up heat sufficiently to reduce the temperature of the water in the piping back to about 120° F. The heated air is then passed through ducts to the rooms to be heated in the regular way.

The third named system would require the water in the exhaust gas heater to be raised to a temperature to produce steam. Each pound of steam at 212° formed from water at 140° requires 1038 B. T. U. As we have available per hour per B. H. P. 2500 B. T. U. from the gas engine, we will be able to raise the temperature of 2.45 lbs. of water to 212° steam or 2.42 lbs. of steam at 15 lbs. gauge pressure. There would be necessitated a considerable increased surface of the ordinary steam radiators used for heating purposes. It is estimated, that 3.6 B. T. U. are required to keep a cubic foot of space at 70° F. when the weather is at zero outside, and that 2.6 B. T. U. are required to maintain a temperature of 70° when the temperature on the outside is 20° F. These figures, however, depend entirely on the building and would have to be varied in special cases.

The above estimates are made with the engine operating at full load or nearly so. When the engine runs at half-load capacity, the heat available would be about 60% of the above figures.

GAS ENGINE PRINCIPLE AND PRACTICE.

HEATING FROM OIL ENGINE.

The following table shows the heat balance of an oil engine.

TABLE XI.

OIL ENGINE, PER ACTUAL HORSE POWER PER HOUR.

B. T. U.	B. T. U.
Received by engine 0.8	Heat equivalent shown
lb. of fuel at 19,000	on brake (82%
B. T. U. per pound,	mech. eff.) 3104
$19,000 \times 0.8$ lb. =	Heat lost to water
15200 B. T. U., . . . 15200	jacket 47.4% 7200
	Heat lost to exhaust
	25% 3800
	Lost in radiation and
	unaccounted for . . . 1096
15200	15200

From these figures it will be noted that more heat is available for heating purposes than is the case with the gas engine, the thermal efficiency of the oil engine being less than that of the average gas engine. 7200 B. T. U. pass away in the water jacket and 3800 B. T. U. in the exhaust gases, thus 11,000 B. T. U. are available with the oil engine as compared with 6825 B. T. U. in the gas engine. Allowing 68% efficiency for the exhaust heater, $11000 \times 0.68 = 7480$ B. T. U. is the waste heat utilized in the oil engine instead of 5500 B. T. U. which are available with the gas engine.

CHAPTER IX.

OPERATION AND CORRECTION.

The engine being installed in accordance with the instructions given in previous chapters and the fuel and other connections having been completed and if in connection with producer, this being in proper working order and ready to furnish gas, as has been described and discussed in Chapter VII, the outfit is ready for operation.

It is necessary before starting the engine to see that the water supply is in proper working order. If cooling water tanks are used, that they are full and that the valves are open so that the water can circulate properly through the cylinder water jacket.

Where engines of larger sizes are started by means of compressed air, instructions for starting with this apparatus are also given in Chapter IV.

PRODUCER GAS.

The supply of gas from the producer before starting the engine must be tested by lighting the gases at the test cocks. The flame should be of a reddish-blue color. It is essential that the gas is of proper composition before endeavoring to start the engine.

ILLUMINATING GAS.

If the supply of gas is taken from the city supply, open the meter cock when the rubber bags should swell up and the

GAS ENGINE PRINCIPLE AND PRACTICE.

proper flow of gas can be ascertained by applying a match to the pet-cock on the drain pipe. The flame at first should be of a bluish color followed by a yellow flame.

ELECTRIC OR TUBE IGNITER.

With the tube igniter which is more commonly used in Europe than in this country, the Bunsen burner heating it is then lighted, the flame being blue in color, which, after burning for about five or ten minutes will raise the ignition tube to the proper temperature, that is, a bright cherry red.

With the electric igniter the contact parts should be tested and where the jump spark and coil is in use its proper operation can be indicated by a notable hum of the vibrator of the coil. Where a magneto, which is fully described in Chapter IV is used, it will be necessary to place the lever or other mechanism so as to retard the timing of the spark before starting.

LUBRICATION AND STARTING.

All lubricators must be attended to, care being taken that they are in proper working order, also that the air and exhaust valves work efficiently. It is essential for the proper operation of a gas or oil engine that suitable lubricating oil be used for oiling the piston. A light mineral product having a flash point not less than about 400° F. is suitable.

With the smaller engines started by hand without the use of automatic starter, the flywheels are turned sharply around, the relief cam to reduce the pressure of compression in the cylinder having been put in operation and the gas valve opened to the proper position as indicated on a dial or otherwise marked. Frequently there are other precautions to

OPERATION AND CORRECTION.

be taken before starting an engine and these are stated in the printed instructions for operating, which usually accompany all engines.

When the engine has been put in operation, the relief cam is placed out of commission, allowing full compression in the cylinder, the gas supply is regulated by the hand lever when afterwards the governor will control automatically the proper supply of gas.

IMPROPER STARTING.

Failure to start the engine may most frequently be attributed to insufficient heating of the tube igniter or with the electric igniter, to its improper working and careful inspection and testing of this device must be made to locate the cause of not sparking properly, as described in Chapter IV.

TIMING OF IGNITION.

Ignition with the tube igniter can usually be varied by altering the position of the heater. Acceleration of the timing of ignition is effected by placing the burner nearer to the cylinder end of the tube. Retarding of the timing of ignition being effected by the reverse action.

Where timing valve is used, the period of opening the valve, of course, regulates the timing of ignition.

With the electric igniter usually a regulating device is fitted to the engine which readily allows variations of the timing of ignition by altering the period of sparking.

AIR AND EXHAUST VALVE TROUBLE.

In some cases the air and exhaust valve will not properly close, thus allowing the pressure of compression to be insuf-

GAS ENGINE PRINCIPLE AND PRACTICE.

ficient. In that event, the valves must be examined and possibly they will require regrinding on their seats. When using illuminating gas from the mains air in the gas main may prevent proper starting. This defect can be ascertained by applying a match to the gas at the pet cock as above referred to or again too great a pressure of gas in the main will allow the supply of gas in the cylinder to be greater than that required for proper explosive mixture and therefore the engine will not readily start.

Leakage past the piston rings again may cause trouble in starting. This, however, can be readily ascertained by noting the action of the piston during the compression period when, if leakage is taking place, blowing of air past the piston rings will be heard. This defect can be remedied by either cleaning the rings or possibly a new set of rings will be required. Where the engine has been in operation for some years it may be that even the cylinder will require reboring and new piston fitted to it, to prevent the leakage.

OVERHEATING OF CYLINDER.

Overheating of the cylinder is due to improper flow of water or to the cylinder water jacket having become coated with scale or to having an accumulation of dirt in it. The proper flow of water where circulating tanks are used can be ascertained by the difference in temperature between the pipe connections to the cylinder and that between the cylinder and tank. The upper pipe should be very much hotter than the lower one. If water is furnished by pump or if water is used from the main the proper flow of water can be ascertained by noting the temperature of the water at the outlet pipe. The

OPERATION AND CORRECTION.

proper temperature should not be greater than about 140° and some makers advise it being as low as 100° to 120° F.

IMPROPER WORKING OF ENGINE.

Irregular running of the engine is due to either the governor not working properly or to the igniter failing to explode each charge. The proper ignition depends upon correct operation of the igniter itself, upon efficient air supply, proper gas supply and proper compression. To insure correct operation, if faulty working is noted, the mechanisms controlling each of these operations must be carefully examined and care taken that they are in good working order.

THUMPING OR KNOCKING OF ENGINE.

Thumping of the engine may be due to premature ignition, which is controlled by the timing of the electric igniter or the proper heating of the tube igniter, or by leakage of the timing valve where such is used in connection with tube igniter, or the space heated in the tube may be too near to the cylinder end of the tube. Premature ignition may also be caused in the cylinder by overheated spots in the cylinder due to improper cooling effect or to angular projections in the cylinder; sometimes premature ignition is due to an incandescent mass of carbon formed in the cylinder. Thumping may be also due to improper supply of gas and further, of course, loose bearings will also cause similar results. It may be necessary to indicate the engine to ascertain the exact cause of the thumping, which process is fully described in Chapter V.

EXPLOSIONS IN SILENCER.

Loud detonations in the exhaust silencer or pipe may be due to unburnt gas having passed through the engine to it or

GAS ENGINE PRINCIPLE AND PRACTICE.

to the slow burning of a weak charge which allows the flame to pass the exhaust valve when open. Too great a supply of gas may have a similar effect, the mixture being too rich for proper combustion in the cylinder and passing to the silencer unburnt or again such detonations may be caused by the exhaust valve not closing properly, or to incorrect setting of the valves.

WATER LEAKAGE IN CYLINDER.

Improper working of engine may be caused by water having entered the cylinder. This will render the engine very difficult to start. The chief cause of this defect is a flaw in the cylinder or combustion chamber casting. The presence of water in the cylinder may in some cases be caused by allowing the water from the exhaust pipe to fill it up and enter the cylinder through exhaust valve. This remark refers more especially to installations where water is allowed to enter the exhaust pipe in order to cleanse or more effectively silence the exhaust.

CHOKING OF EXHAUST PIPE. .

Occasionally choking of the exhaust pipe by either carbon or water will prevent the proper working of the engine and cause difficulty in starting. Where improper combustion has been allowed to take place this may occur and especially with fuel oil or kerosene engines of the two-cycle type.

LOSS OF POWER.

Loss of power in the engine may be due to improper lubrication of the piston or other parts; to improperly timed ignition, leakage of the valves, incorrect gas supply, loss of com-

OPERATION AND CORRECTION.

pression; in some cases also leakage of water into cylinder, overheating of the cylinder due to improper water supply as already explained.

An engine working properly will work smoothly without knocking or vibration and without variation in speed.

PRECAUTION.

Whenever it is necessary to examine the engine, care must be taken that all possibility of presence of gas in the cylinder or other parts is removed and therefore it is necessary to turn the engine once or twice by hand after the gas supply has been shut off. If it is not possible to turn the engine by hand, the valves and the pet-cock on the cylinder should be opened. No light should be brought in contact with the cylinder or valve openings while there is any possibility of the presence of an explosive mixture.

GASOLINE ENGINES.

The gasoline engine which is now universally in use on automobiles, launches and for stationary purposes is similar in all respects to the gas engine and many of the above instructions are applicable to its operation. It has, however, in addition apparatus for carburetting or vaporizing the liquid fuel and mixing it with the air to be drawn into the cylinder. The carbureter may be taken as the chief feature peculiar to this engine. The function of the carbureter is to furnish a homogeneous mixture of gasoline and air, that is, a mixture with practically unvarying proportions, at all speeds of the engine which it supplies and with a varying range of temperature and further securing proper regulation at varying loads.

The gasoline enters the air passage at its point of greatest

GAS ENGINE PRINCIPLE AND PRACTICE.

velocity by means of a small orifice, either by suction or pressure and only during the suction stroke of the engine. The regulation is secured by some form of valve placed between valves and fuel inlet.

The Kingston carbureter may be taken as a good representative type of the many apparatus on the market as it is very extensively in use.

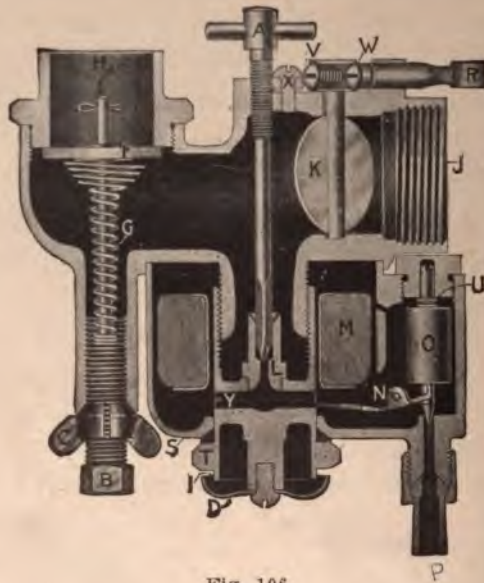


Fig. 106.

Figure 106 shows sectional view of the 1907 Kingston vertical carbureter and the horizontal type is shown in sectional view at Fig. 107, in this carbureter the auxilliary air enters through passage H and compensating valve F which is held in position by spring G, the strength of which is regulated by adjustment of screw B and lock nut C. The gasoline enters through connection at P and is maintained at constant level by float valve O having spring at U. The

OPERATION AND CORRECTION.

fuel passes to the sprayer through recess Y and comes in contact with the air on passing through this sprayer. The carburetted mixture passes to the motor cylinder through opening J after passing the throttle valve K.

The carbureter is attached to the air inlet of the engine and in automobiles one supplies several cylinders.

Two-cycle marine engines seldom change speed so the throttle valves are omitted, the gasoline entering through a

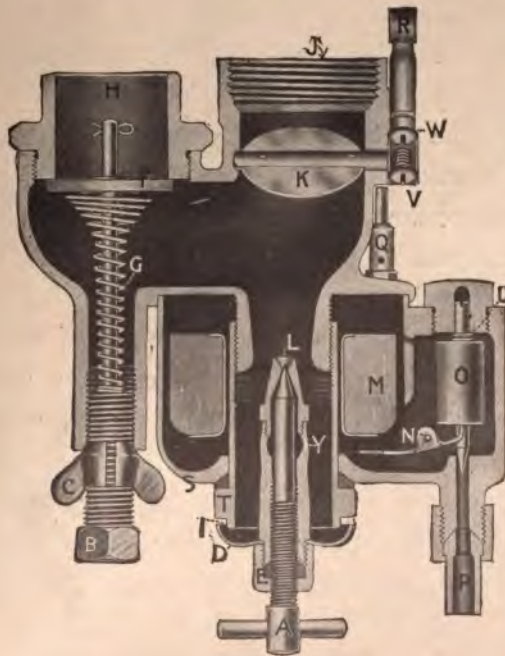


Fig. 107.

small orifice drilled in the valve seat when uncovered by the valve lifting on the suction stroke.

The engine troubles caused by carbureters are usually due to the float sticking allowing the engine to be flooded;

GAS ENGINE PRINCIPLE AND PRACTICE.

the orifice becoming clogged, the velocity of air being insufficient to lift the gasoline, especially in starting.

KEROSENE ENGINES.

While many of the above remarks refer to the operation of the kerosene or oil engine, it is necessary with this type; to insure proper operation, to note that the correct amount of fuel be supplied to the vaporizer or cylinder.

Improper working of the engine is frequently due to the supply of too much fuel. Sufficient fuel only is required to form a proper explosive mixture. If too much fuel is supplied the mixture may become too rich for explosion.

With the type of engine having automatic igniter, such as the "Hornsby-Akroyd" oil engine, it is necessary to see that efficient compression of the charge before ignition takes place, the compression pressure being governed by the correct setting of the valves and the proper closing of the valves. The fuel supply depends upon the length of the stroke of the oil pump and the oil inlet and overflow valves being without leakage. The oil pipes, of course, must also be tight.

With this type of engine it is also necessary to see that the temperature of the vaporizer or other igniter is sufficient to cause ignition of the explosive mixture.

—FINIS—

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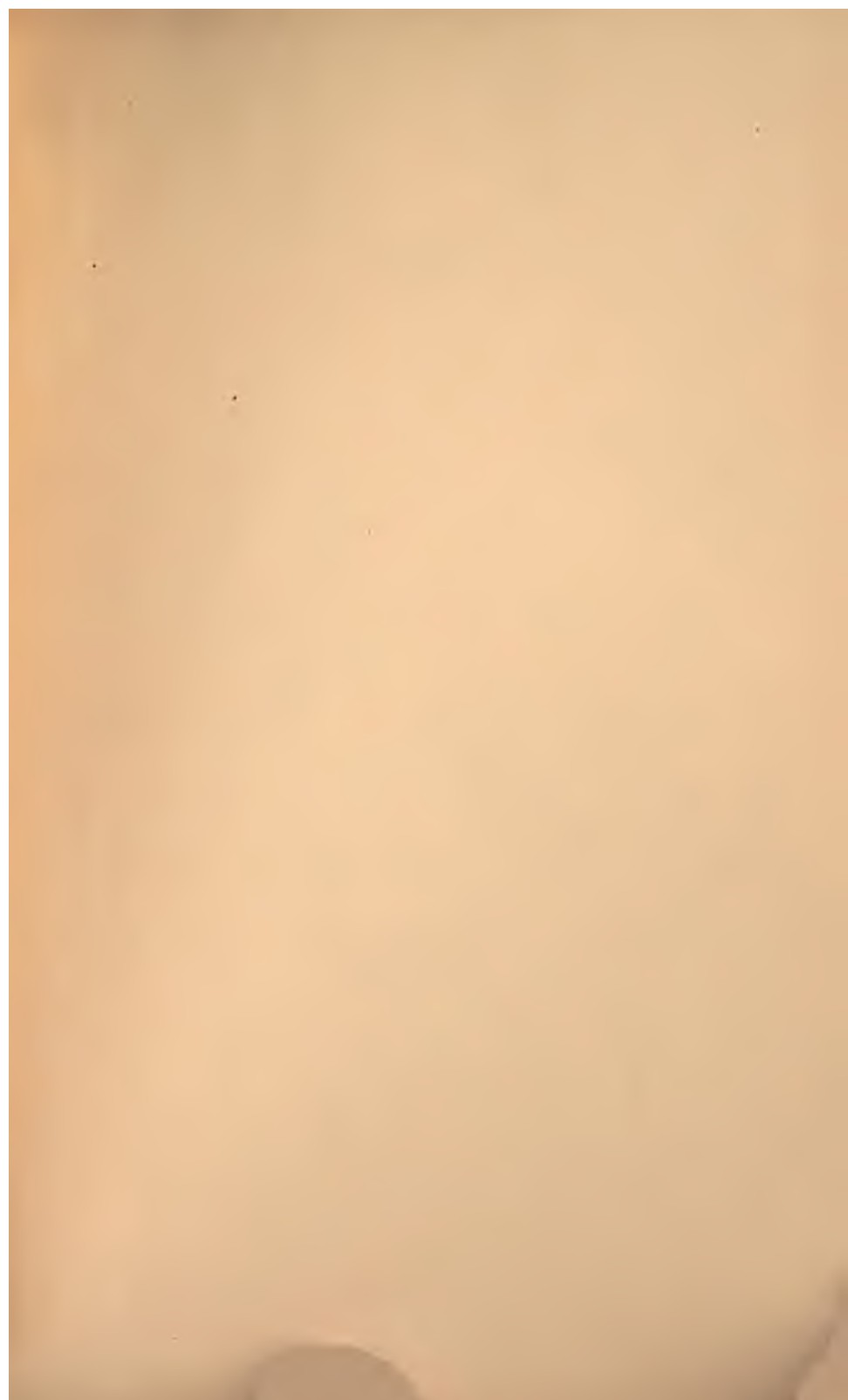
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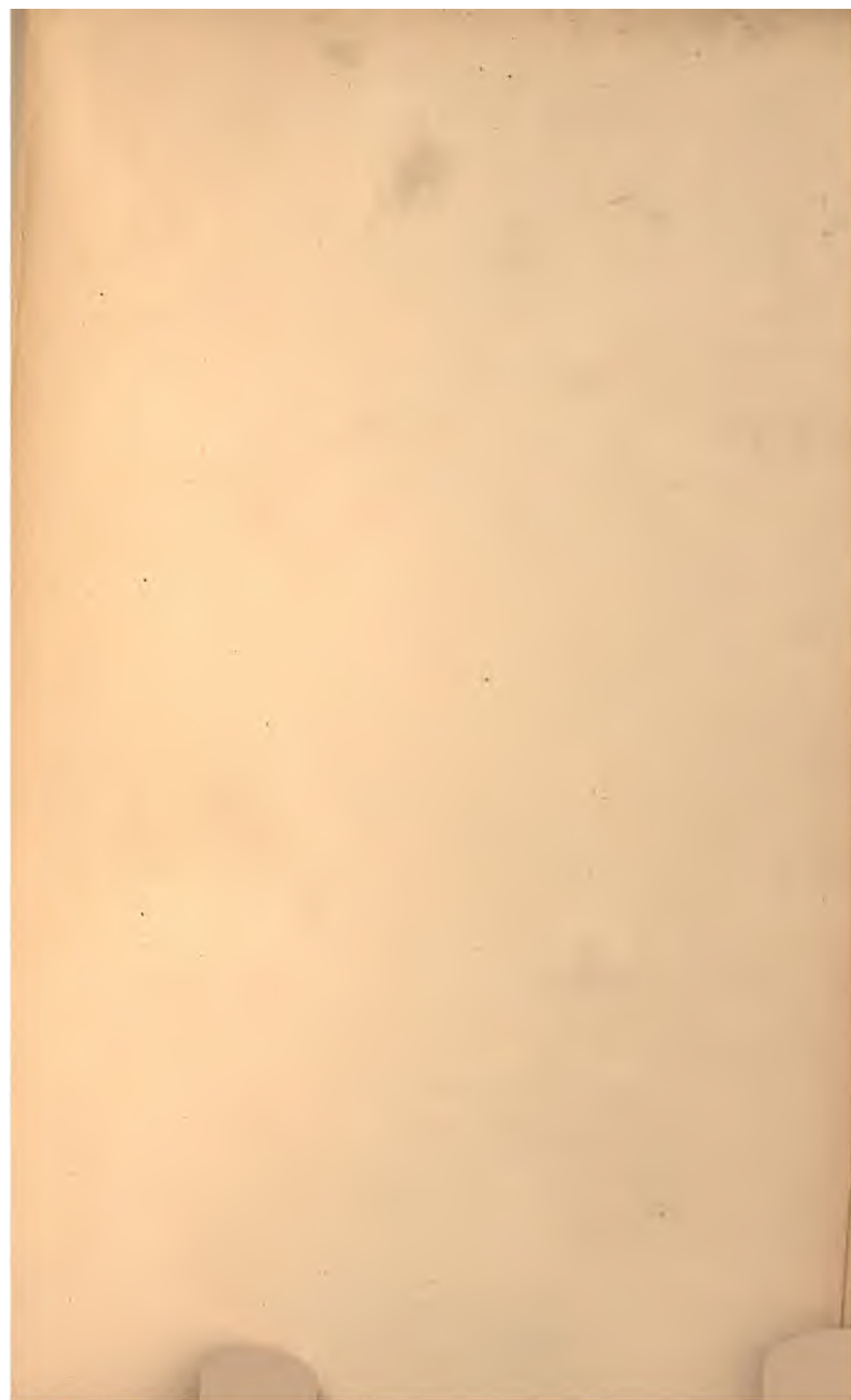
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